US009176176B2

(12) **United States Patent**
Dembo et al.

(10) **Patent No.: US 9,176,176 B2**
(45) **Date of Patent: Nov. 3, 2015**

(54) **RADIO FIELD INTENSITY MEASUREMENT DEVICE, AND RADIO FIELD INTENSITY DETECTOR AND GAME CONSOLE USING THE SAME**

(71) Applicant: **Semiconductor Energy Laboratory Co., Ltd.**, Atsugi-shi, Kanagawa-ken (JP)

(72) Inventors: **Hiroki Dembo**, Isehara (JP); **Atsushi Miyaguchi**, Atsugi (JP)

(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd.**, Atsugi-shi, Kanagawa-ken (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 398 days.

(21) Appl. No.: **13/706,630**

(22) Filed: **Dec. 6, 2012**

(65) **Prior Publication Data**

US 2013/0106663 A1 May 2, 2013

Related U.S. Application Data

(63) Continuation of application No. 13/479,401, filed on May 24, 2012, now Pat. No. 8,330,607, which is a continuation of application No. 13/270,399, filed on Oct. 11, 2011, now Pat. No. 8,188,875, which is a continuation of application No. 11/979,472, filed on Nov. 5, 2007, now Pat. No. 8,044,813.

(30) **Foreign Application Priority Data**

Nov. 16, 2006 (JP) 2006-309996

(51) **Int. Cl.**
G08B 21/00 (2006.01)
G01R 29/08 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G01R 29/0878*** (2013.01); ***G01R 29/0857*** (2013.01); ***H01Q 1/248*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/248; G01R 29/0857
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,512,823	A	4/1996	Nepveu
6,131,038	A	10/2000	Sekine

(Continued)

FOREIGN PATENT DOCUMENTS

CA	2013776		10/1992
CN	2368040	Y	3/2000

(Continued)

OTHER PUBLICATIONS

European Search Report (Application No. 07021488.7) Dated Jan. 8, 2014.

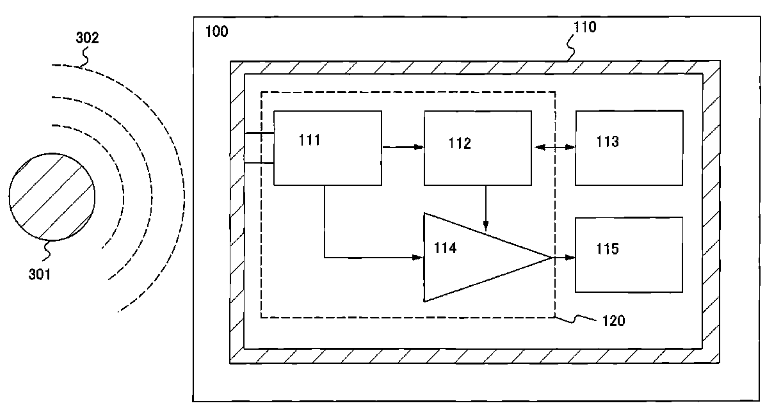
(Continued)

Primary Examiner — Trinh Dinh
(74) *Attorney, Agent, or Firm* — Eric J. Robinson; Robinson Intellectual Property Law Office, P.C.

(57) **ABSTRACT**

The present invention provides a radio field intensity measurement device having a display portion with improved visibility, in the case of measuring a weak radiowave from a long distance. In the radio field intensity measurement device, a battery is provided as a power source for power supply and the battery is charged by a received radiowave. When a potential of a signal obtained from the received radiowave is higher than an output potential of the battery, the power is stored in the battery. On the other hand, when the potential of the signal obtained from the received radiowave is lower than the output potential of the battery, power produced by the battery is used as power to drive the radio field intensity measurement device. As an element to display the radio field intensity, a thermochromic element or an electrochromic element is used.

17 Claims, 38 Drawing Sheets



(51) **Int. Cl.**

H01Q 1/24	(2006.01)
H01Q 1/28	(2006.01)
H01Q 1/38	(2006.01)
H02J 7/02	(2006.01)
H02J 17/00	(2006.01)
H04B 1/16	(2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/28*** (2013.01); ***H01Q 1/38*** (2013.01); ***H02J 7/025*** (2013.01); ***H02J 17/00*** (2013.01); ***H04B 1/1607*** (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,489,883	B1	12/2002	Iiyama et al.	
6,761,637	B2	7/2004	Weston et al.	
6,809,498	B2	10/2004	Nakamura et al.	
7,224,143	B2 *	5/2007	Liscio et al.	320/114
7,445,550	B2	11/2008	Barney et al.	
7,471,188	B2	12/2008	Koyama et al.	
7,500,917	B2	3/2009	Barney et al.	
7,659,892	B2	2/2010	Tanada et al.	
7,710,270	B2	5/2010	Shionoiri et al.	
7,714,535	B2	5/2010	Yamazaki et al.	
7,764,046	B2	7/2010	Osada	
7,839,124	B2	11/2010	Yamazaki et al.	
7,850,527	B2	12/2010	Barney et al.	
7,878,905	B2	2/2011	Weston et al.	
7,881,693	B2	2/2011	Kurokawa	
7,896,742	B2	3/2011	Weston et al.	
7,898,537	B2	3/2011	Tanada et al.	
7,965,180	B2	6/2011	Koyama	
8,030,643	B2	10/2011	Asami et al.	
8,044,813	B1	10/2011	Dembo et al.	
8,089,458	B2	1/2012	Barney et al.	
8,159,088	B2	4/2012	Tanada et al.	
8,164,567	B1	4/2012	Barney et al.	
8,169,406	B2	5/2012	Barney et al.	
8,184,097	B1	5/2012	Barney et al.	
8,188,875	B2 *	5/2012	Dembo et al.	340/635
8,238,152	B2	8/2012	Asami et al.	
8,248,367	B1	8/2012	Barney et al.	
8,330,284	B2	12/2012	Weston et al.	
8,330,607	B2 *	12/2012	Dembo et al.	340/635
8,368,648	B2	2/2013	Barney et al.	
8,373,659	B2	2/2013	Barney et al.	
8,384,668	B2	2/2013	Barney et al.	
8,455,954	B2	6/2013	Suzuki et al.	
8,526,216	B2	9/2013	Asami et al.	
8,749,063	B2	6/2014	Tsurume	
2002/0190689	A1	12/2002	Nakamura et al.	
2003/0078731	A1	4/2003	Nakamura	
2004/0257064	A1	12/2004	Ito	
2006/0202269	A1	9/2006	Suzuki et al.	
2006/0267769	A1	11/2006	Ito et al.	
2007/0163010	A1	7/2007	Ishii	
2007/0229228	A1	10/2007	Yamazaki et al.	
2007/0229279	A1	10/2007	Yamazaki et al.	
2007/0278998	A1	12/2007	Koyama	
2007/0285246	A1	12/2007	Koyama	
2008/0016961	A1 *	1/2008	Dwyer et al.	73/504.02
2008/0055047	A1	3/2008	Osada et al.	
2008/0055279	A1	3/2008	Osada et al.	
2008/0058029	A1	3/2008	Sato et al.	
2008/0060422	A1	3/2008	Hosoya	
2008/0101267	A1 *	5/2008	Kurokawa	370/310
2008/0169349	A1 *	7/2008	Suzuki et al.	235/492
2008/0210762	A1 *	9/2008	Osada et al.	235/492
2009/0121675	A1	5/2009	Ho et al.	
2011/0081970	A1	4/2011	Barney et al.	
2011/0300941	A1	12/2011	Weston et al.	
2012/0139714	A1	6/2012	Tanada et al.	
2012/0258802	A1	10/2012	Weston et al.	
2013/0079141	A1	3/2013	Barney et al.	
2014/0014953	A1	1/2014	Asami et al.	

FOREIGN PATENT DOCUMENTS

CN	2471040		1/2002
CN	2550773	Y	5/2003
CN	2616914		5/2004
DE	19852525		5/2000
EP	1263114	A	12/2002
EP	1722284	A	11/2006
EP	1724649	A	11/2006
EP	1729187	A	12/2006
JP	10-197581	A	7/1998
JP	10-222108	A	8/1998
JP	3063391		10/1999
JP	11-345292	A	12/1999
JP	2000-224775	A	8/2000
JP	2001-165973		6/2001
JP	2001-218958	A	8/2001
JP	2003-111301	A	4/2003
JP	2003-259570	A	9/2003
JP	2004-252522	A	9/2004
JP	2005-149118	A	6/2005
JP	2005-204493	A	7/2005
JP	2005-310128	A	11/2005
JP	2006-023817		1/2006
JP	2006-237581	A	9/2006
JP	2006-521162		9/2006
JP	2006-285958	A	10/2006
JP	2006-296187	A	10/2006
JP	2006-310799	A	11/2006
WO	WO-91/15800		10/1991
WO	WO-03/083495		10/2003
WO	WO-2004/087271		10/2004
WO	WO-2006/039339		4/2006
WO	WO-2006/080322		8/2006
WO	WO-2007/058996		5/2007

OTHER PUBLICATIONS

Chinese Office Action (Application No. 201110320811.6) Dated Nov. 25, 2013.

Chinese Office Action (Application No. 200710169455.6) dated Jan. 26, 2011.

* cited by examiner

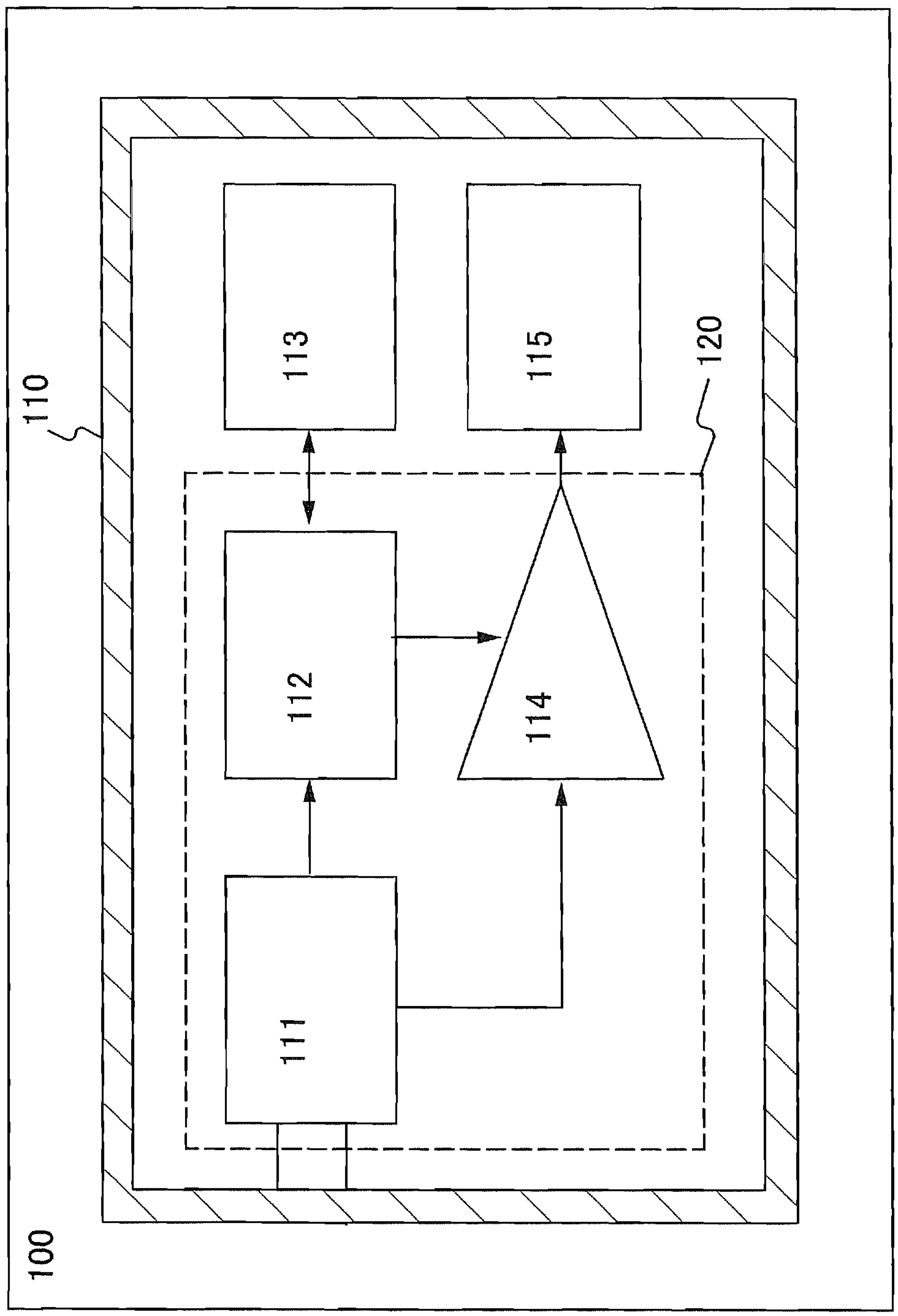


FIG. 1

FIG. 2

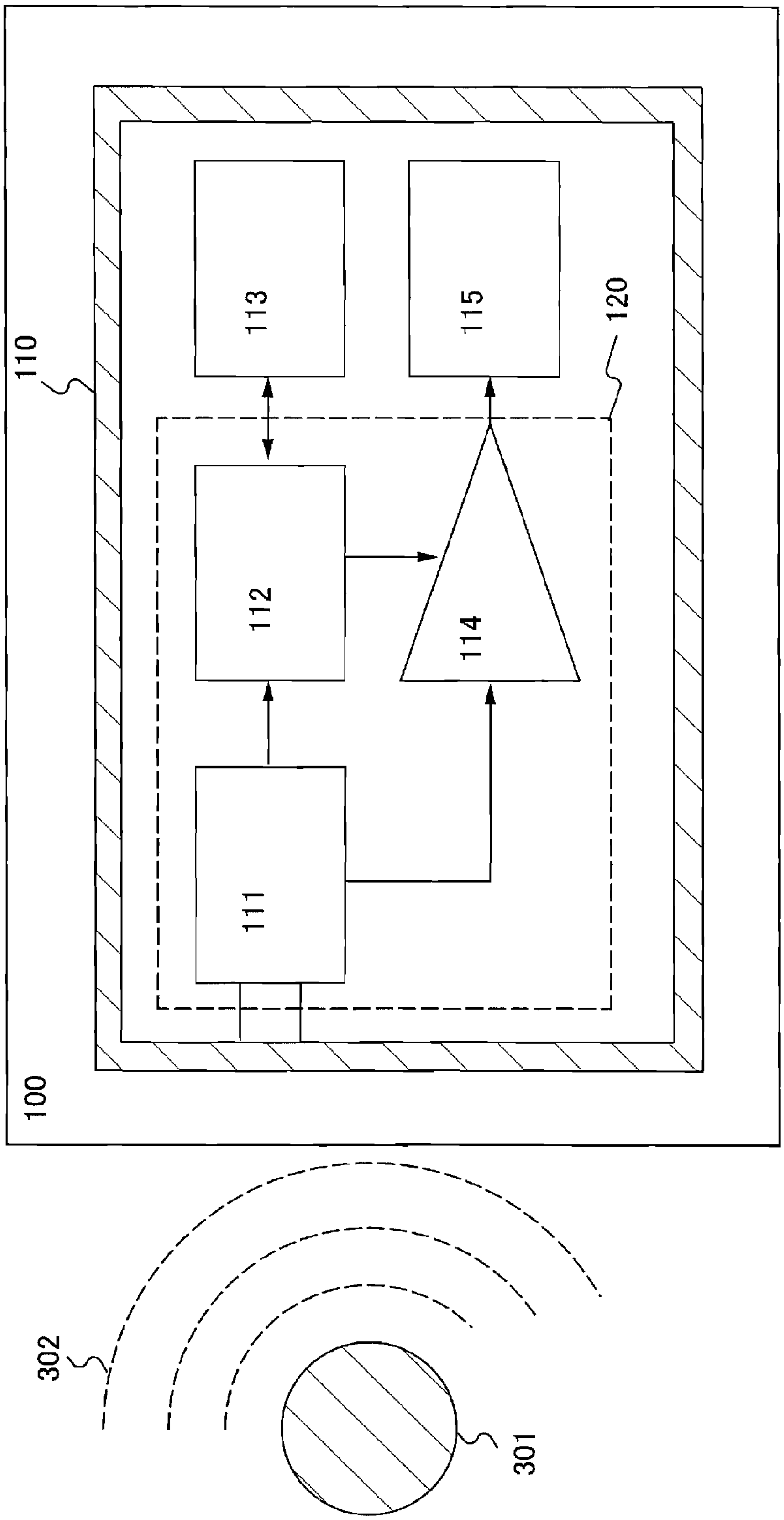


FIG. 3A

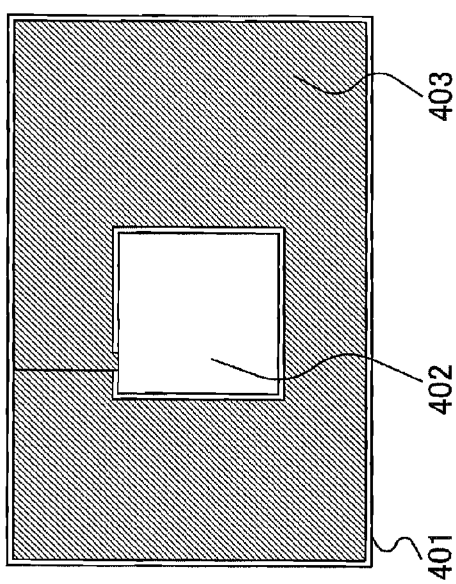


FIG. 3B

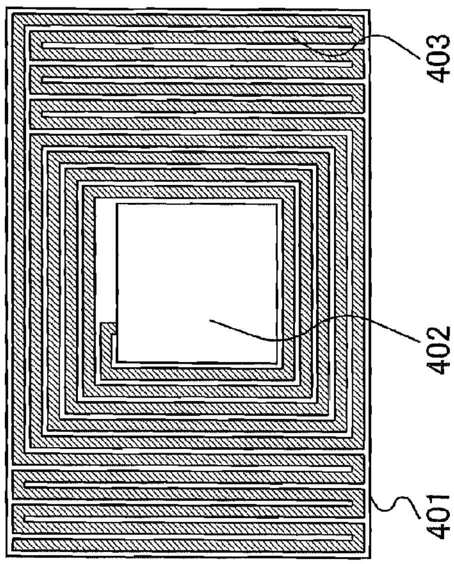


FIG. 3C

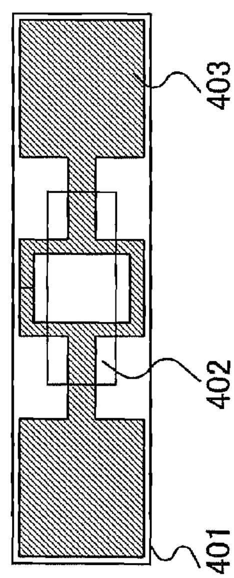


FIG. 3D

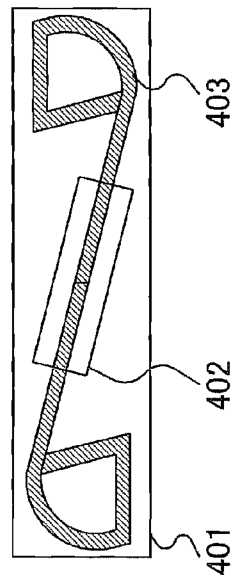
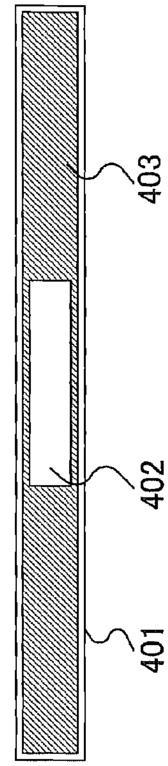


FIG. 3E



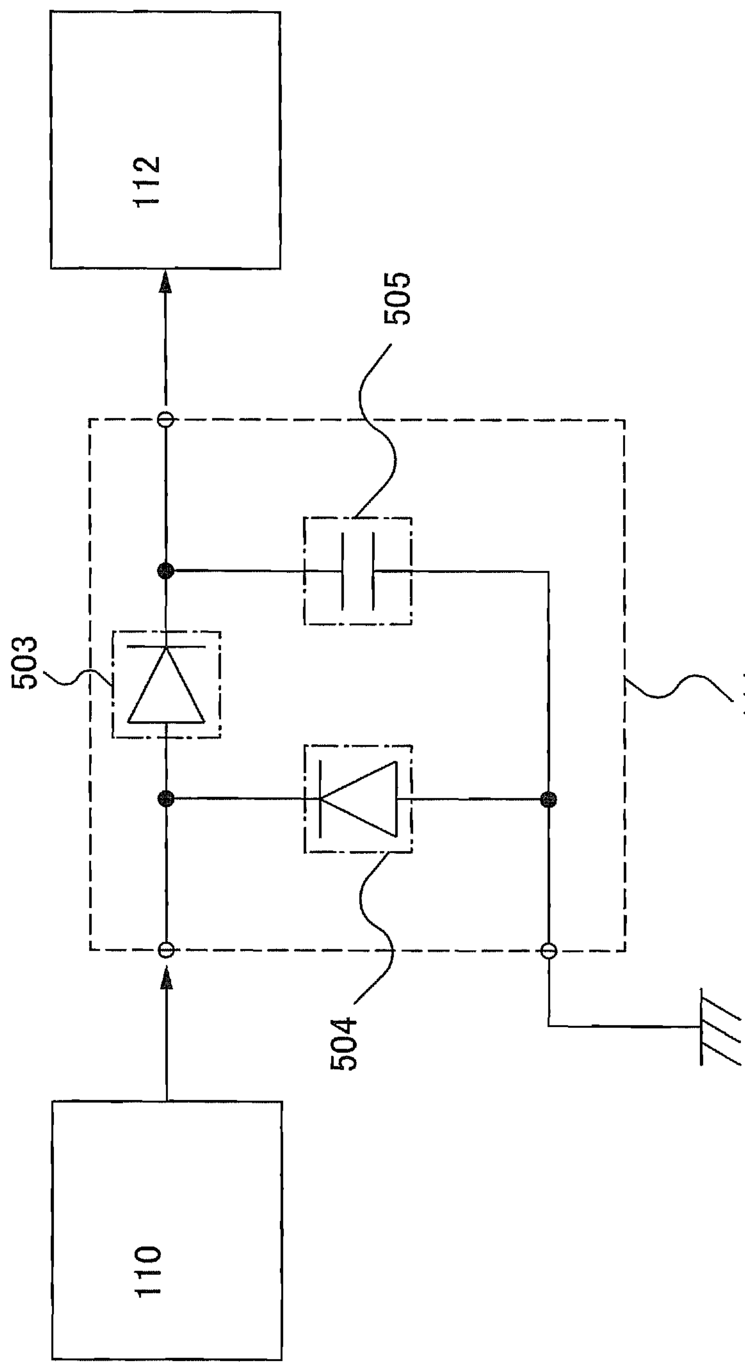


FIG. 4

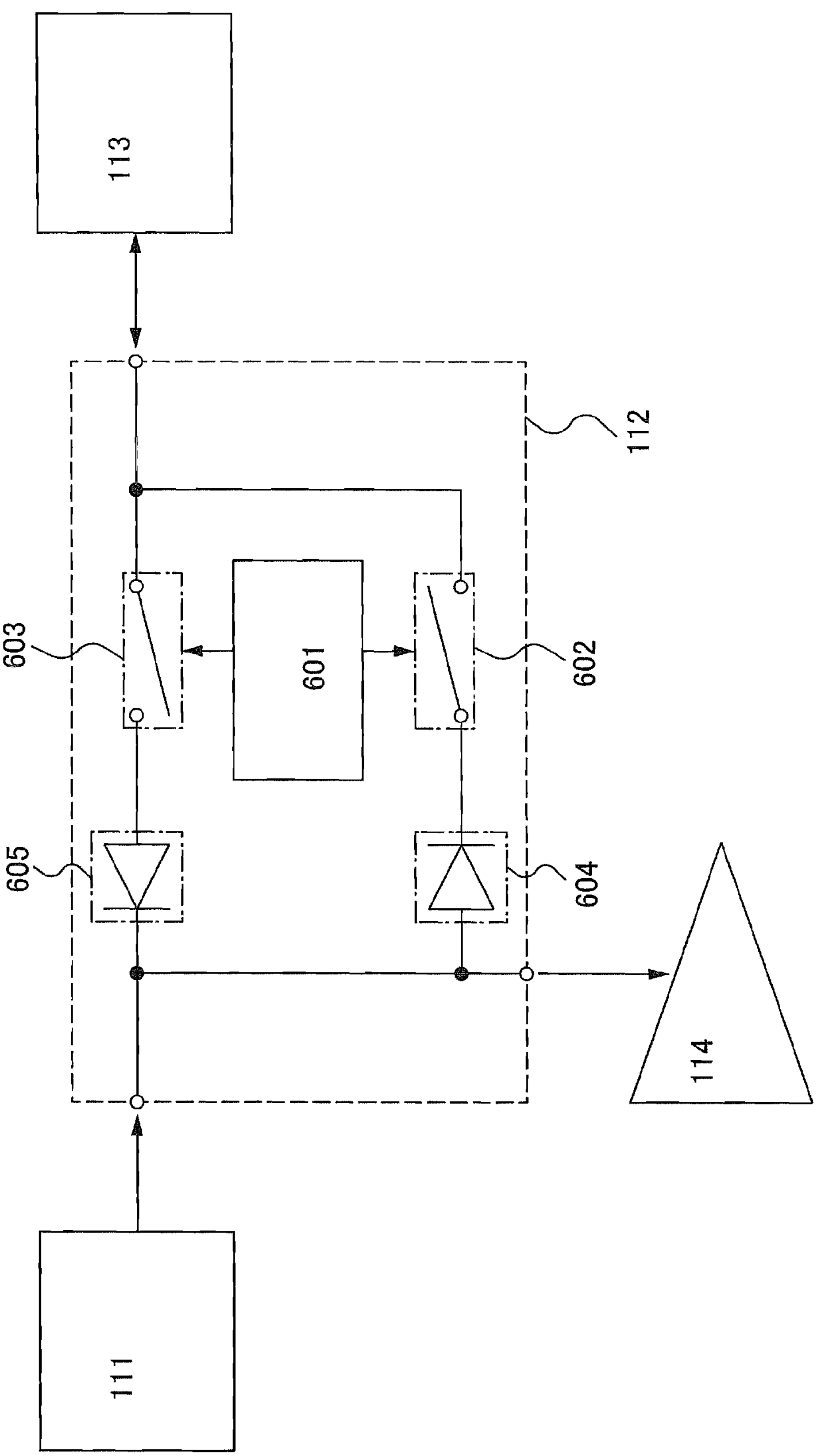
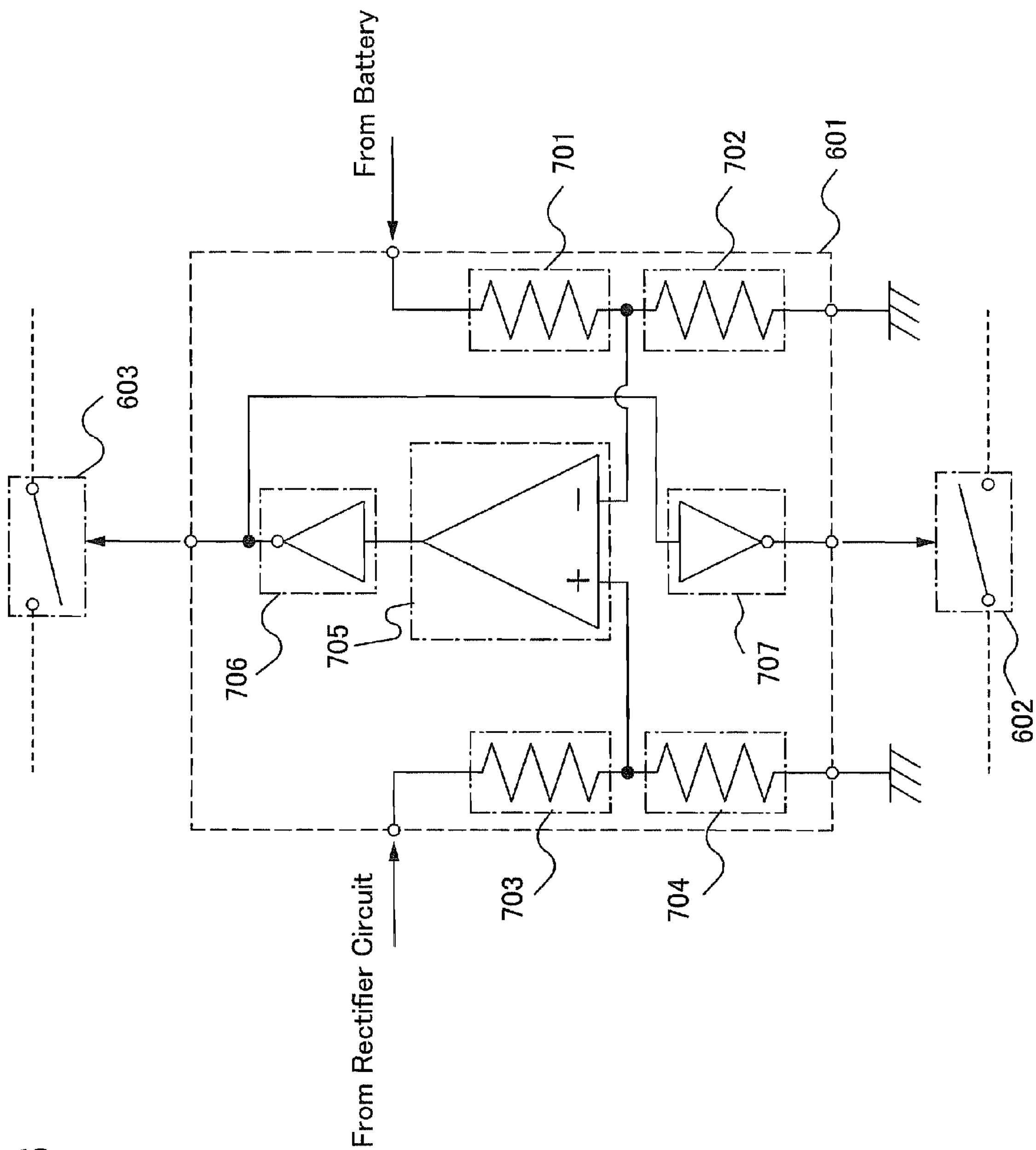


FIG. 5

FIG. 6


From Battery
From Rectifier Circuit
601
602
603
701
702
703
704
705
706
707

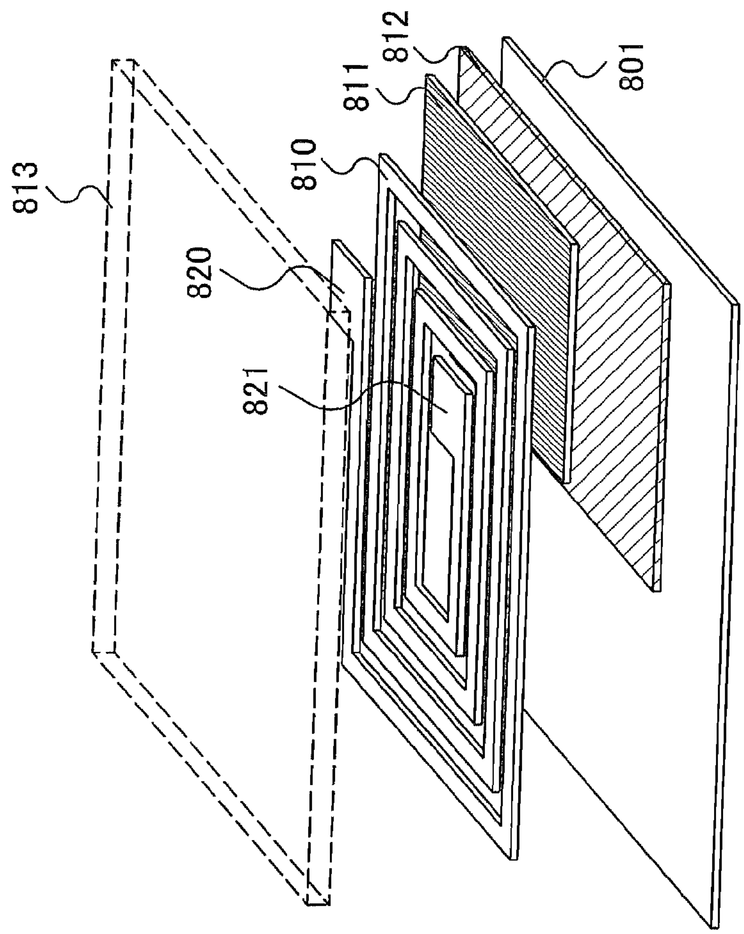


FIG. 7B

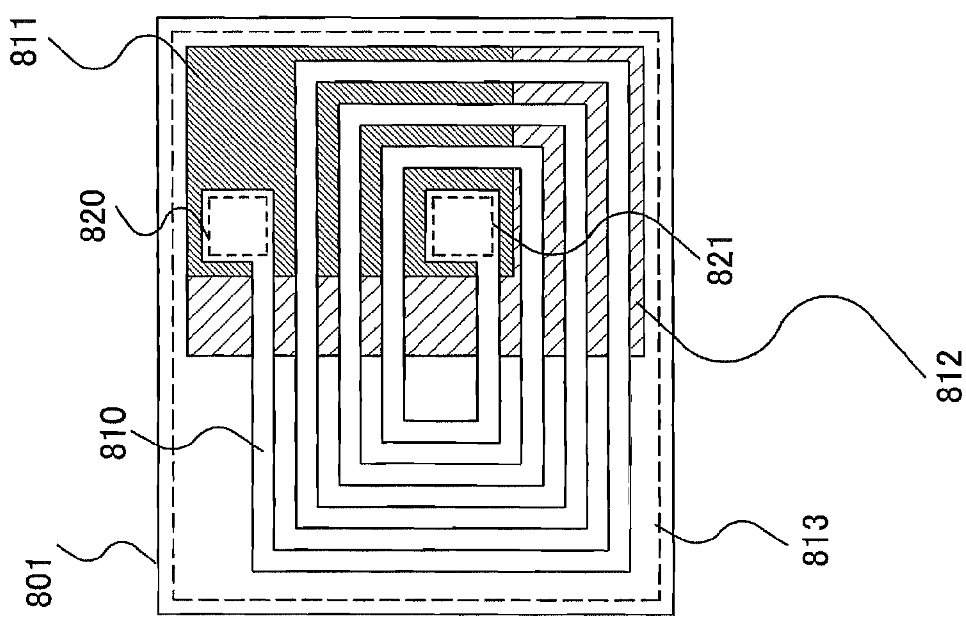


FIG. 7A

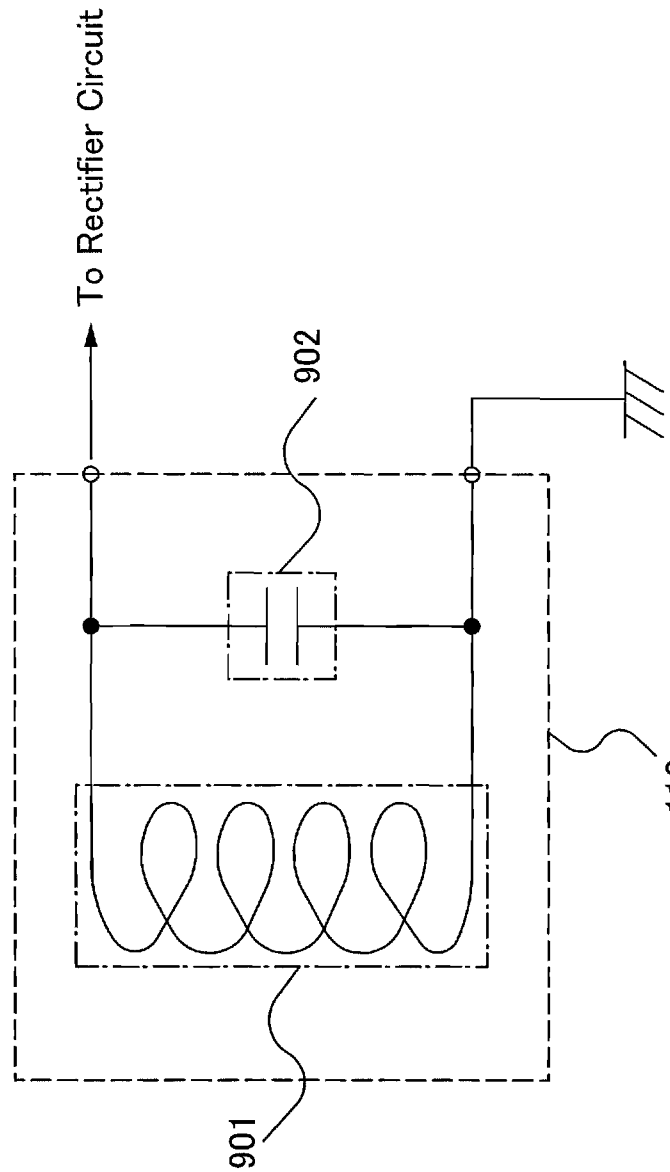


FIG. 8

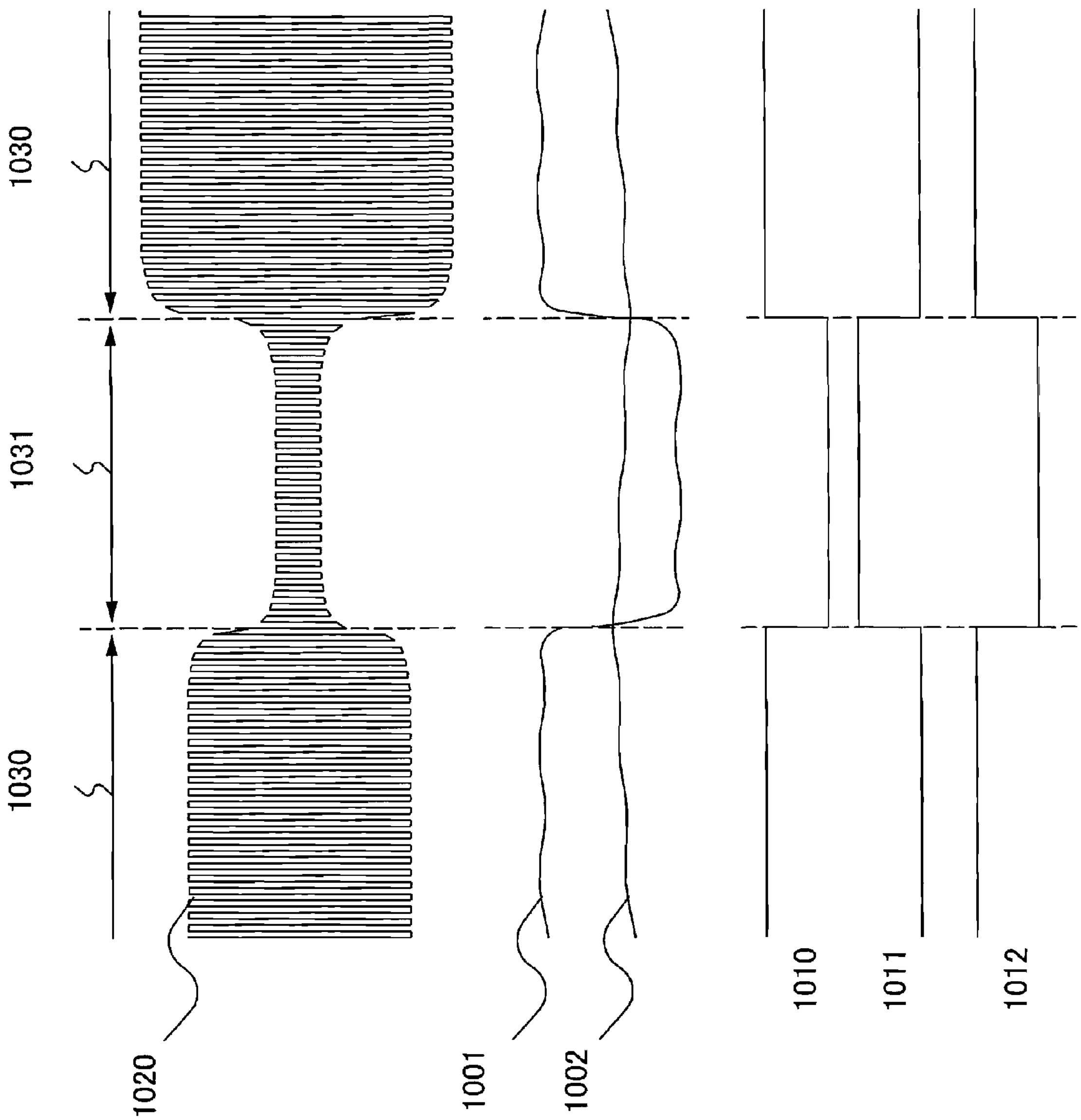


FIG. 9

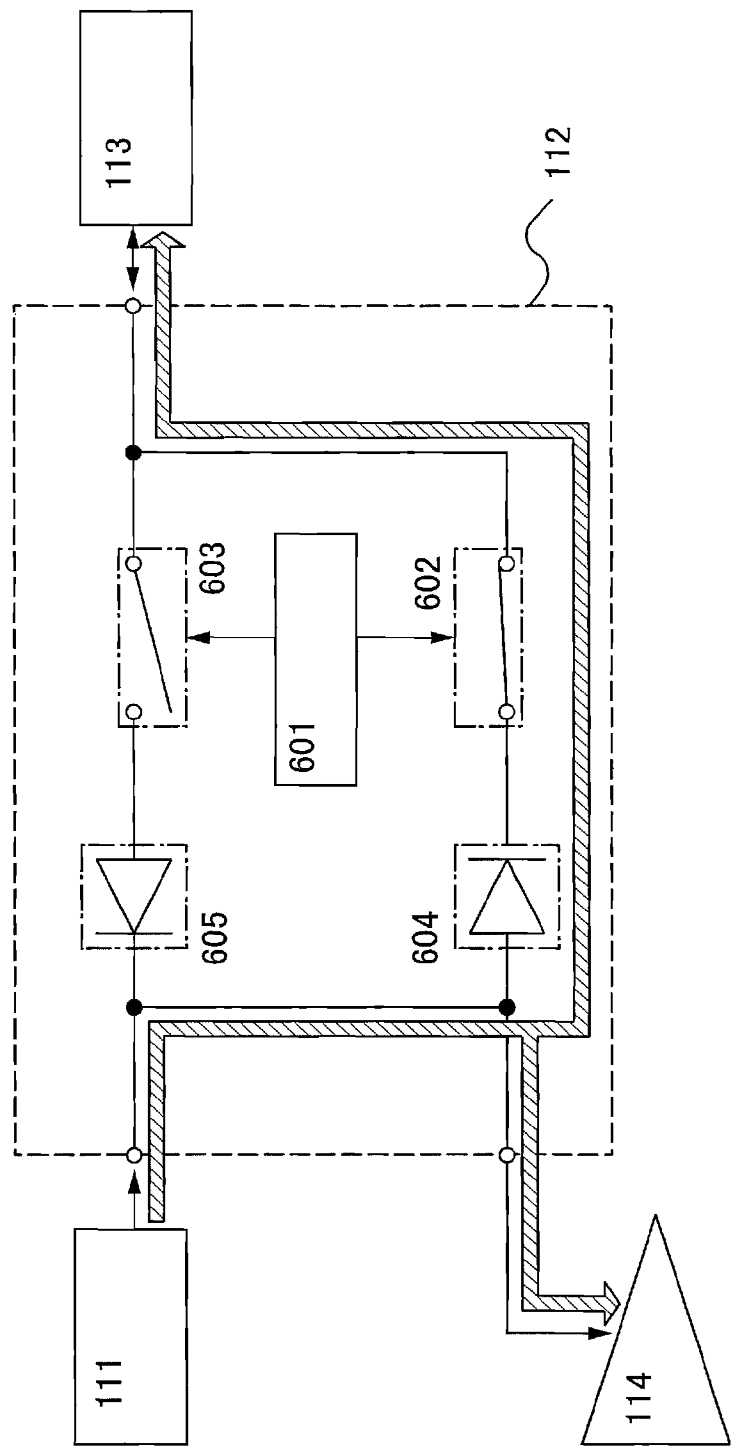


FIG. 10

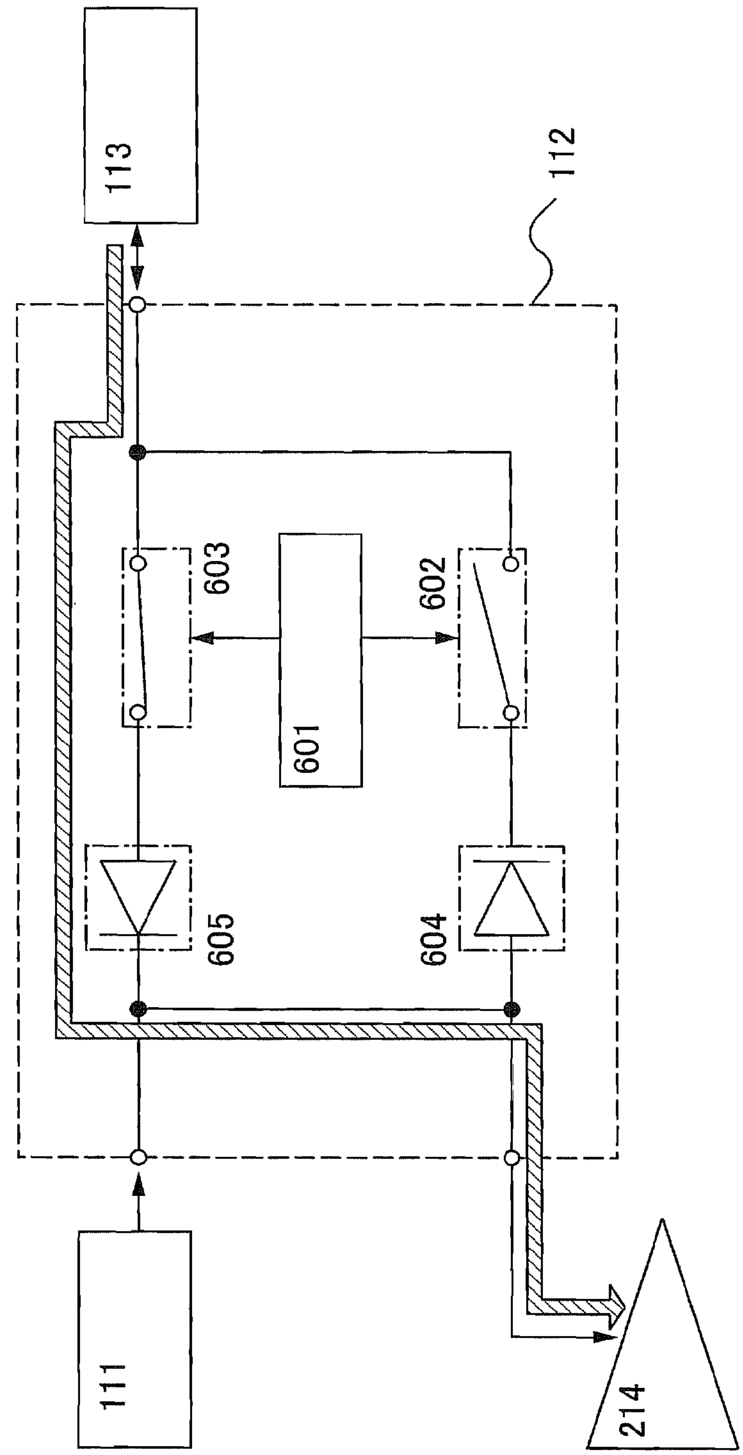


FIG. 11

FIG. 12

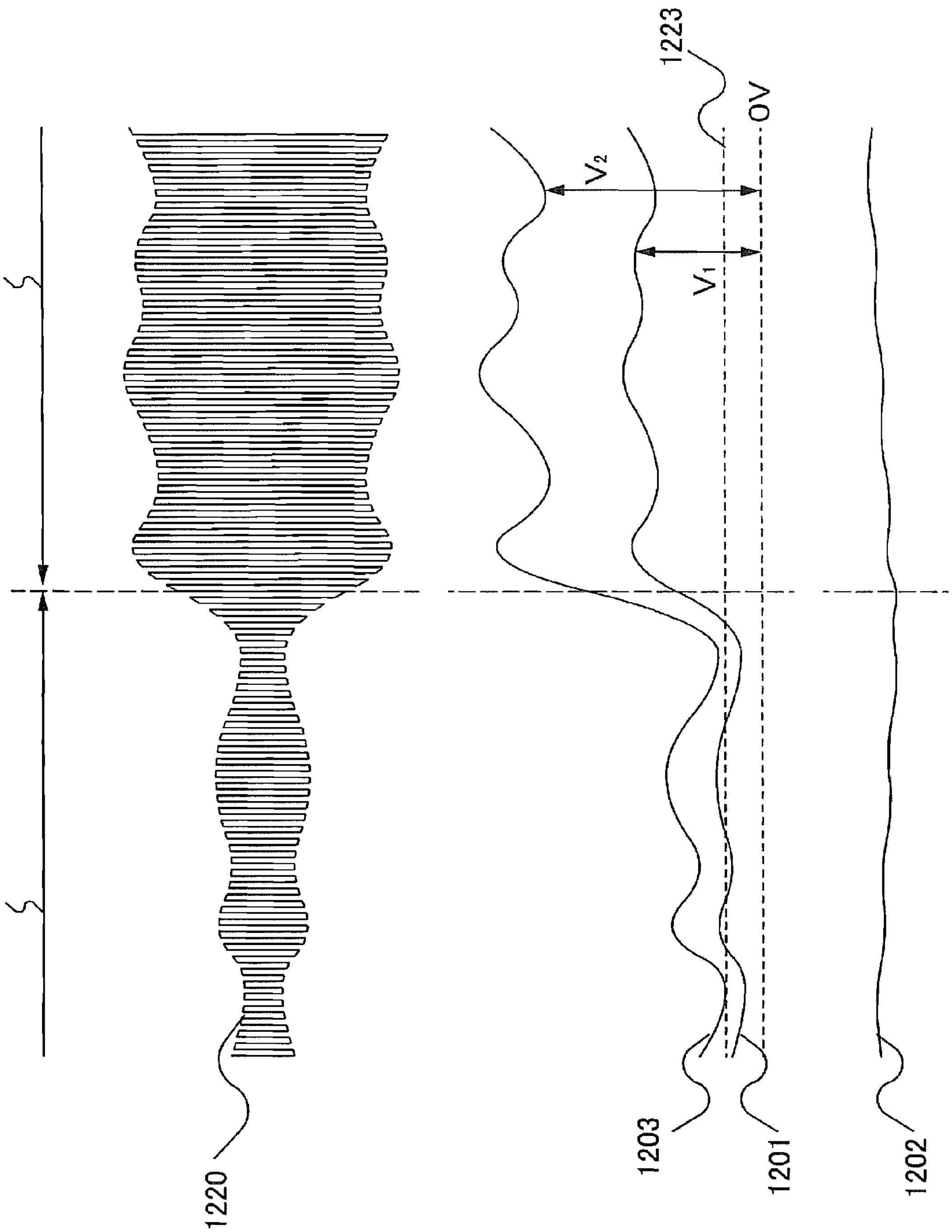


FIG. 13A

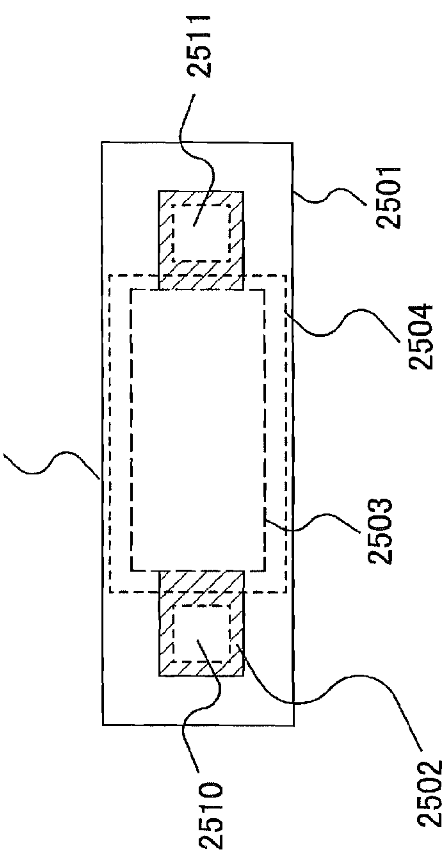
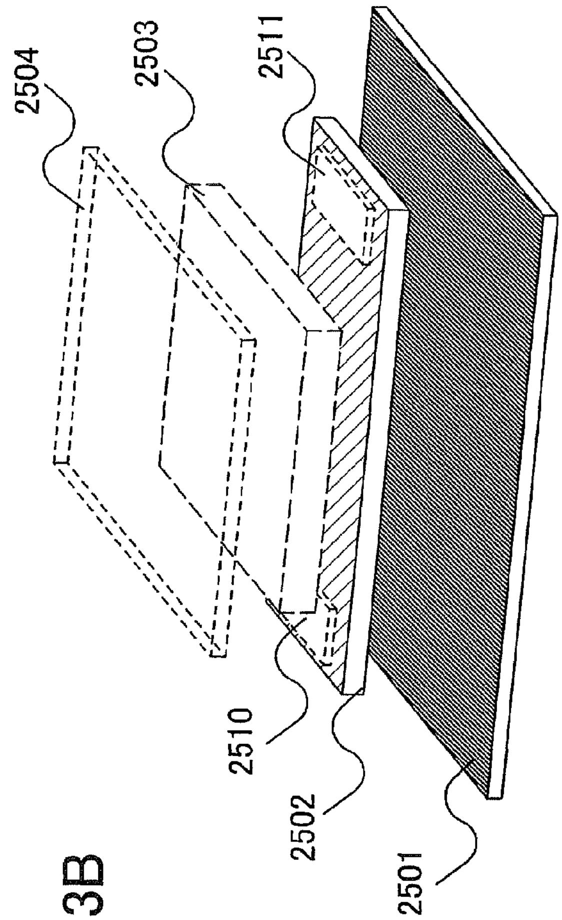


FIG. 13B



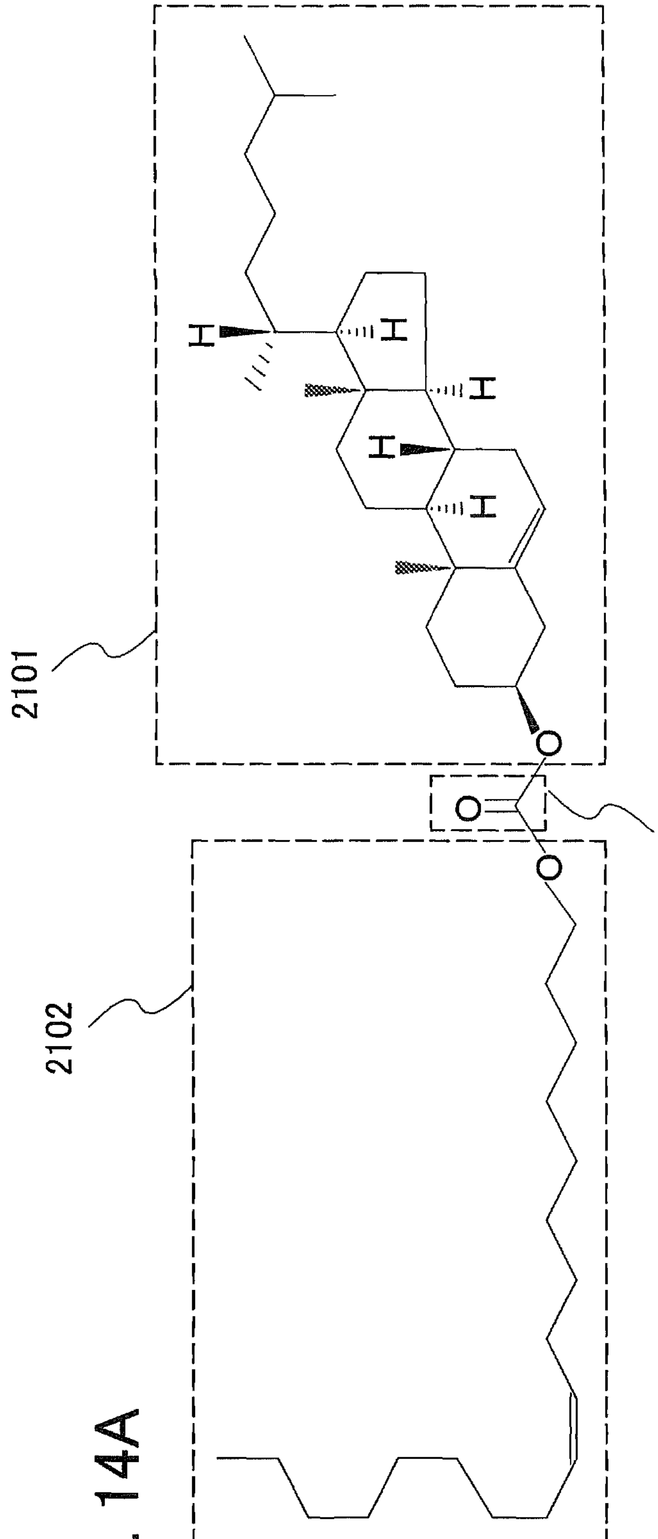


FIG. 14A

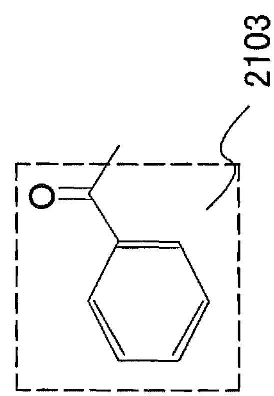


FIG. 14B

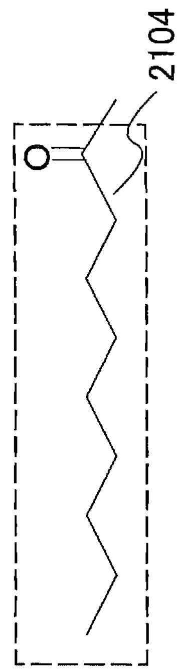


FIG. 14C

FIG. 15A

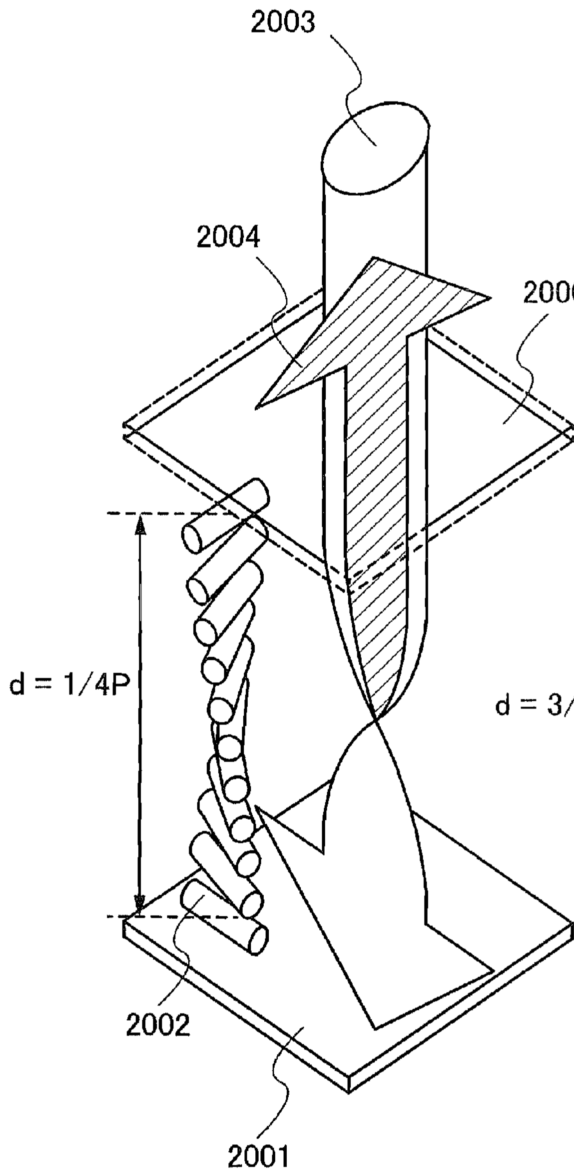


FIG. 15B

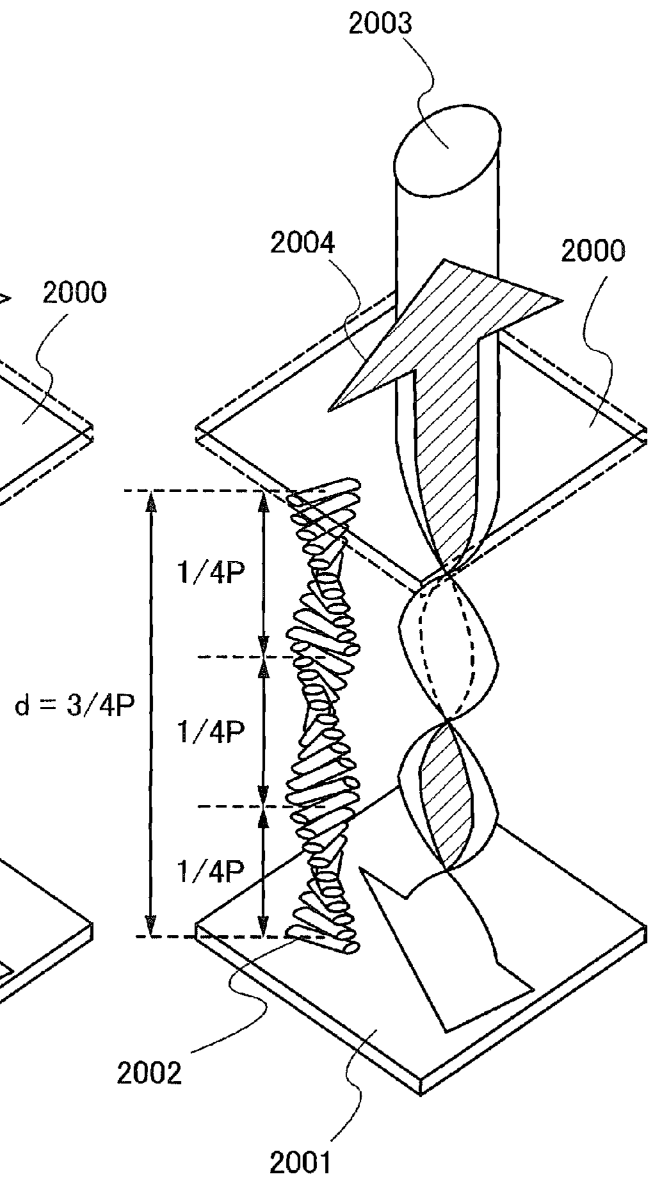
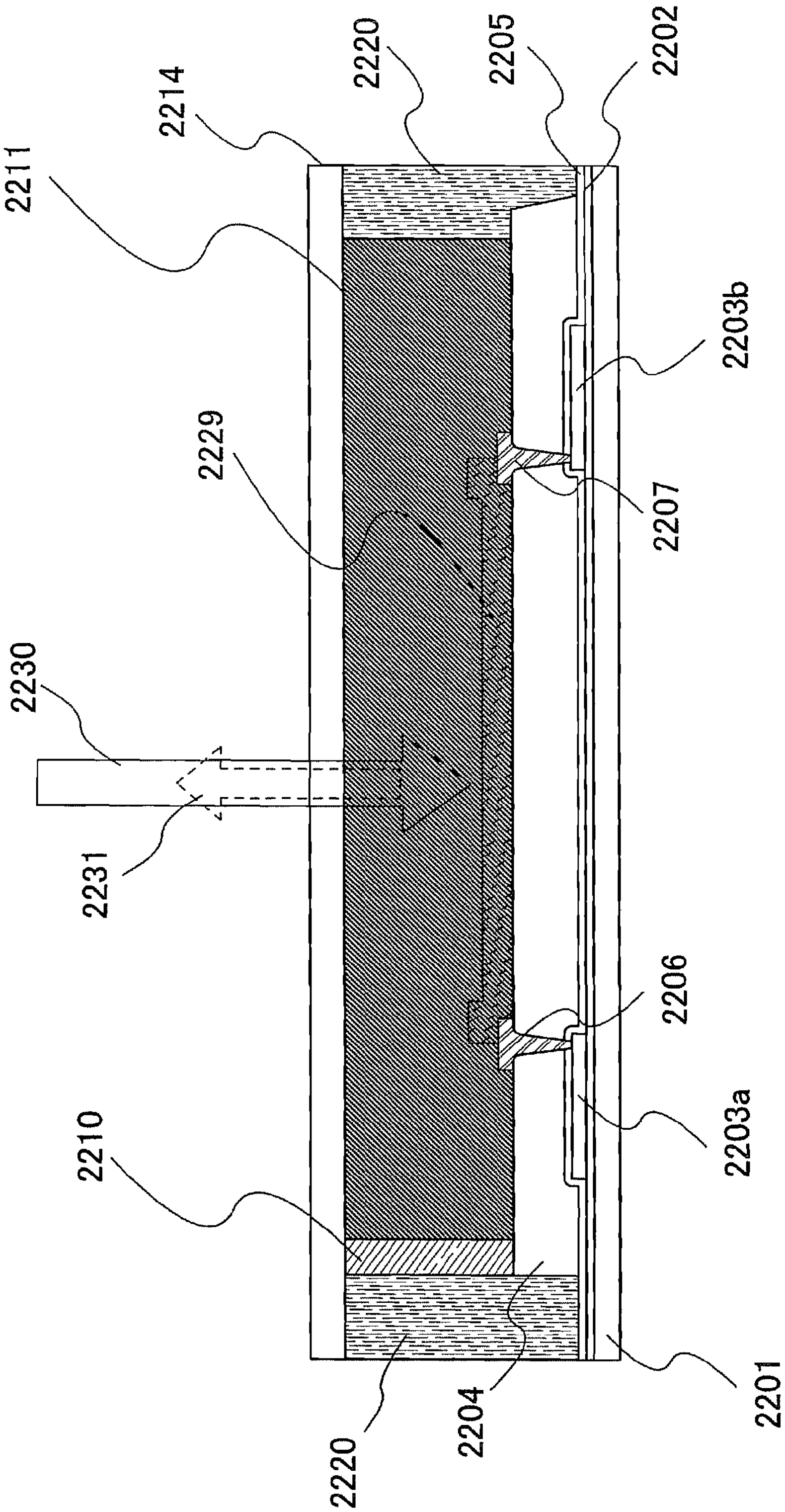


FIG. 16


2220
2205
2202
2214
2211
2203b
2229
2207
2230
2231
2206
2210
2203a
2220
2204
2201

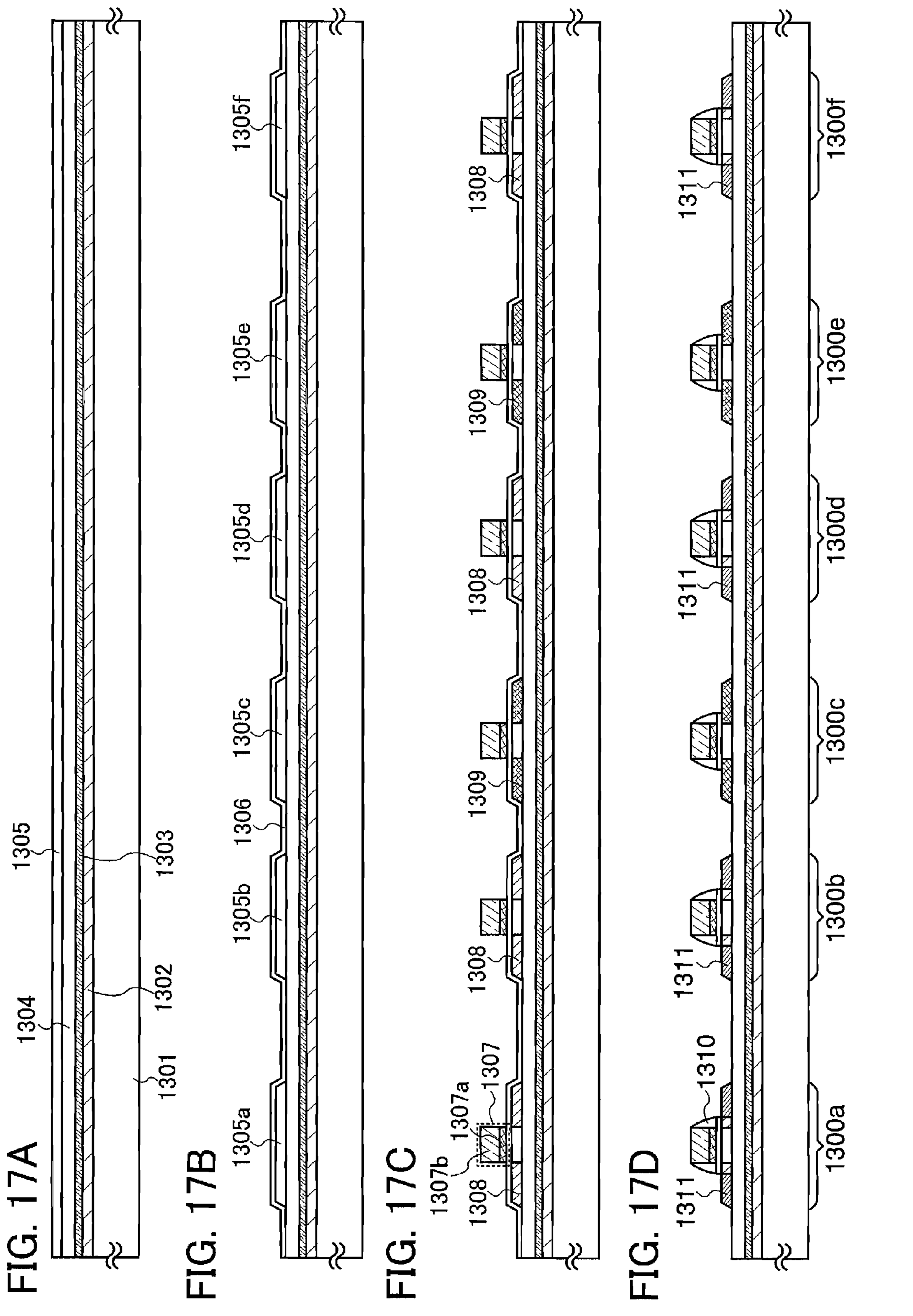


FIG. 17A

FIG. 17B

FIG. 17C

FIG. 17D

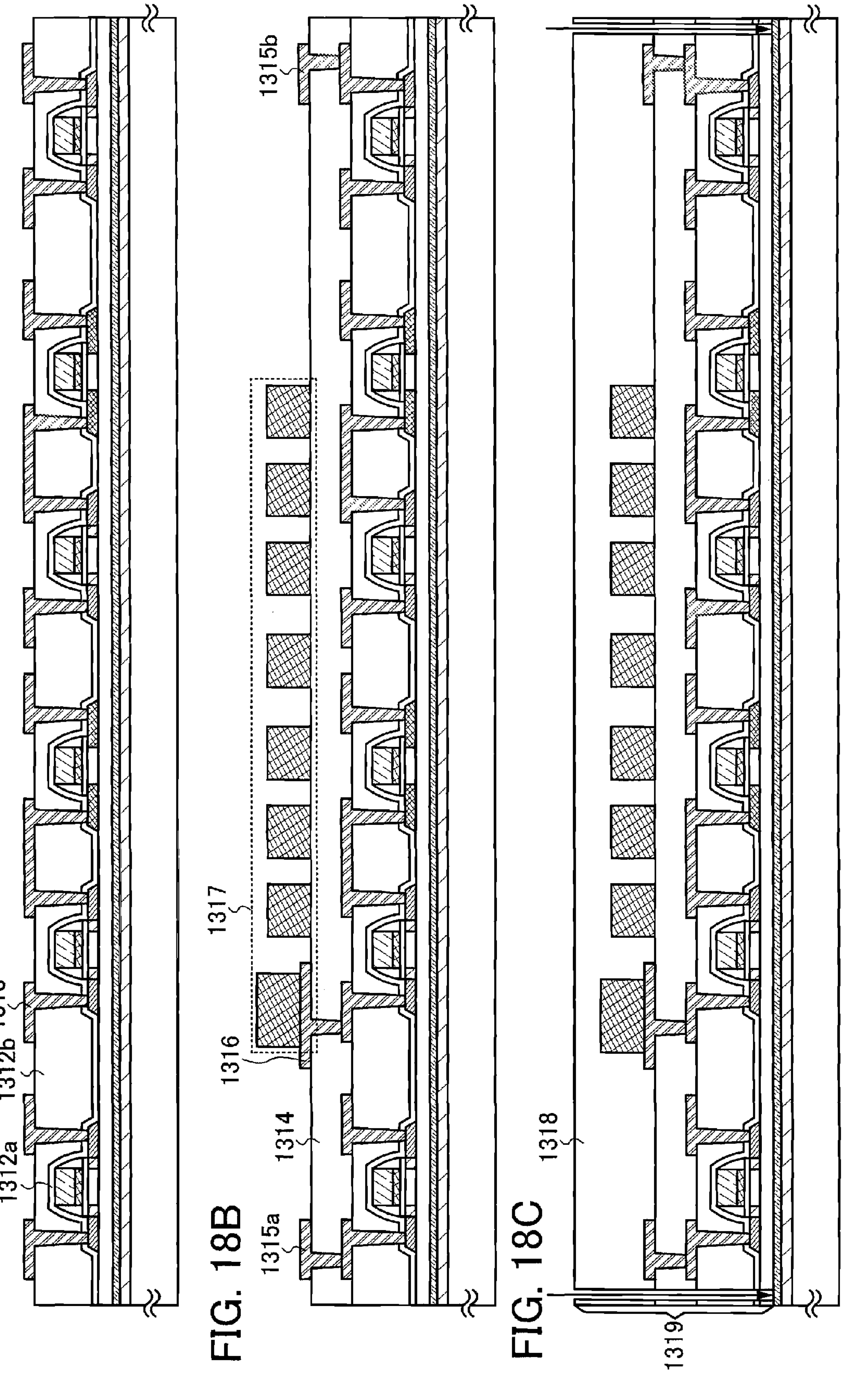


FIG. 18A

FIG. 18B

FIG. 18C

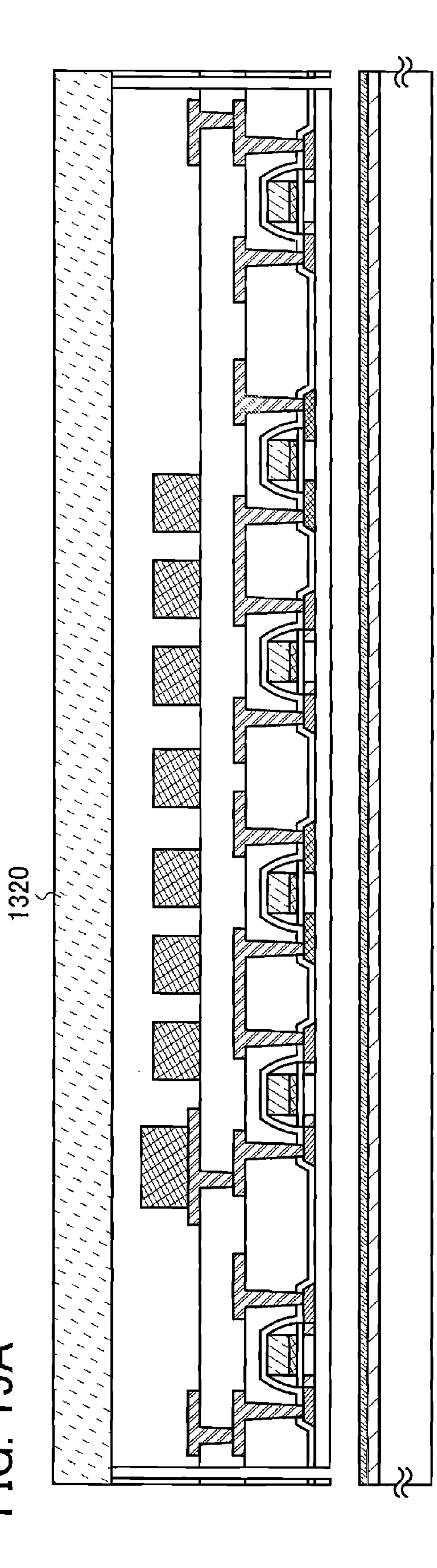


FIG. 19A

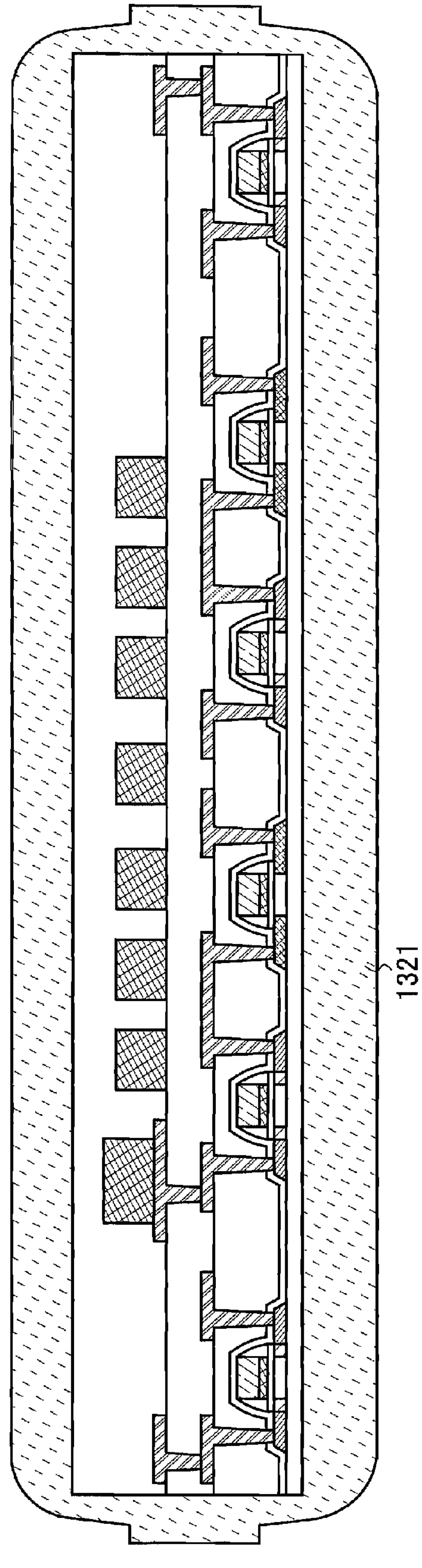


FIG. 19B

FIG. 20A

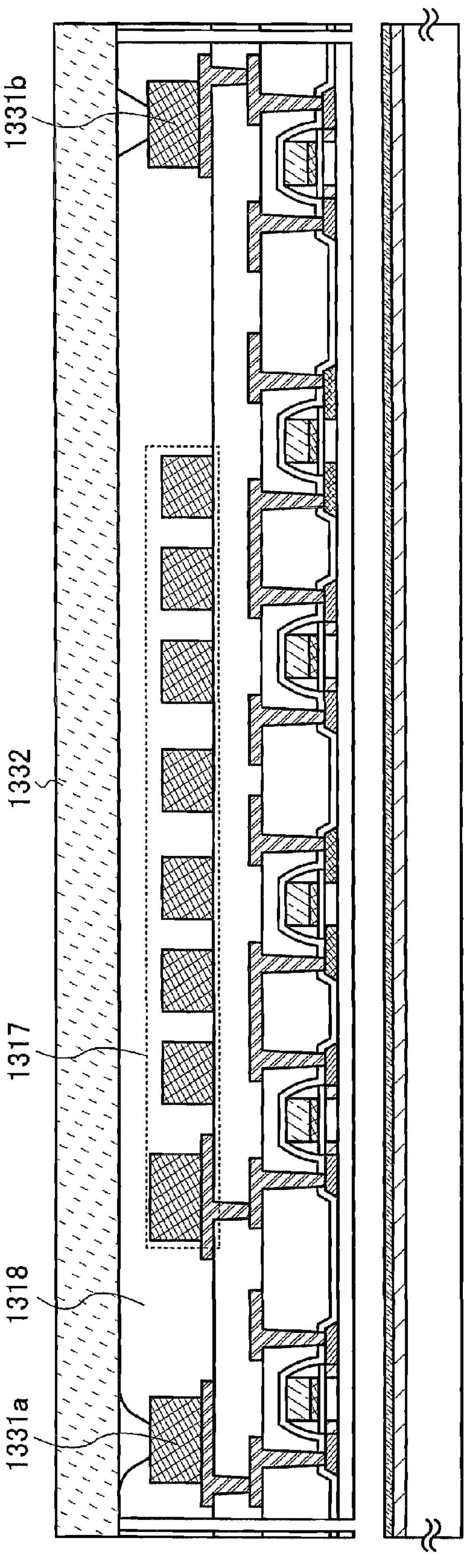
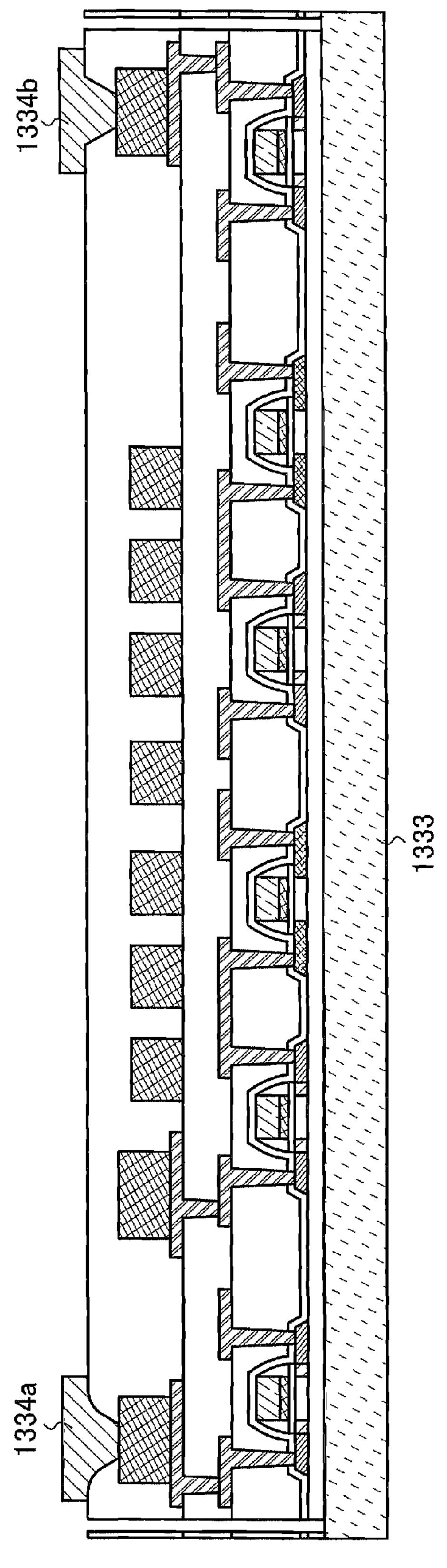


FIG. 20B



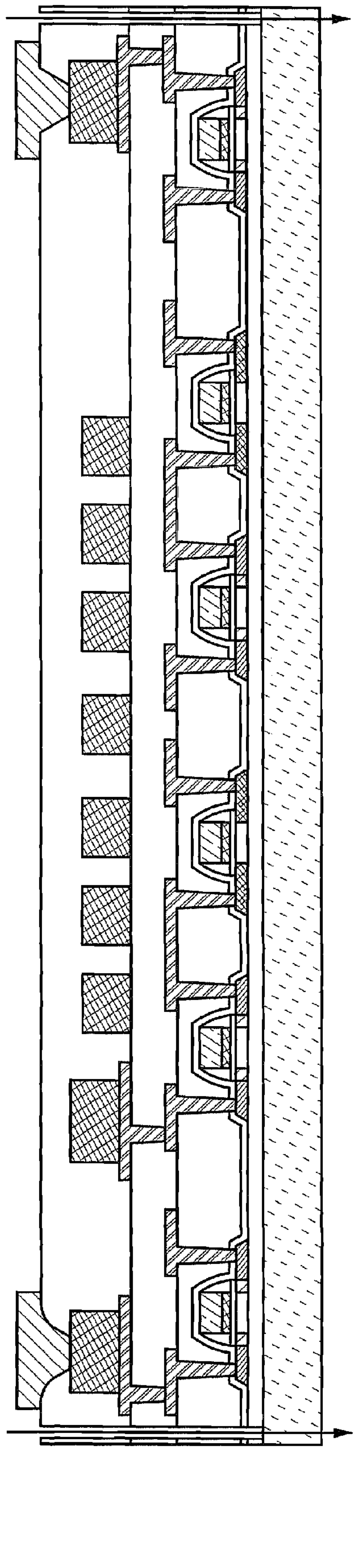


FIG. 21A

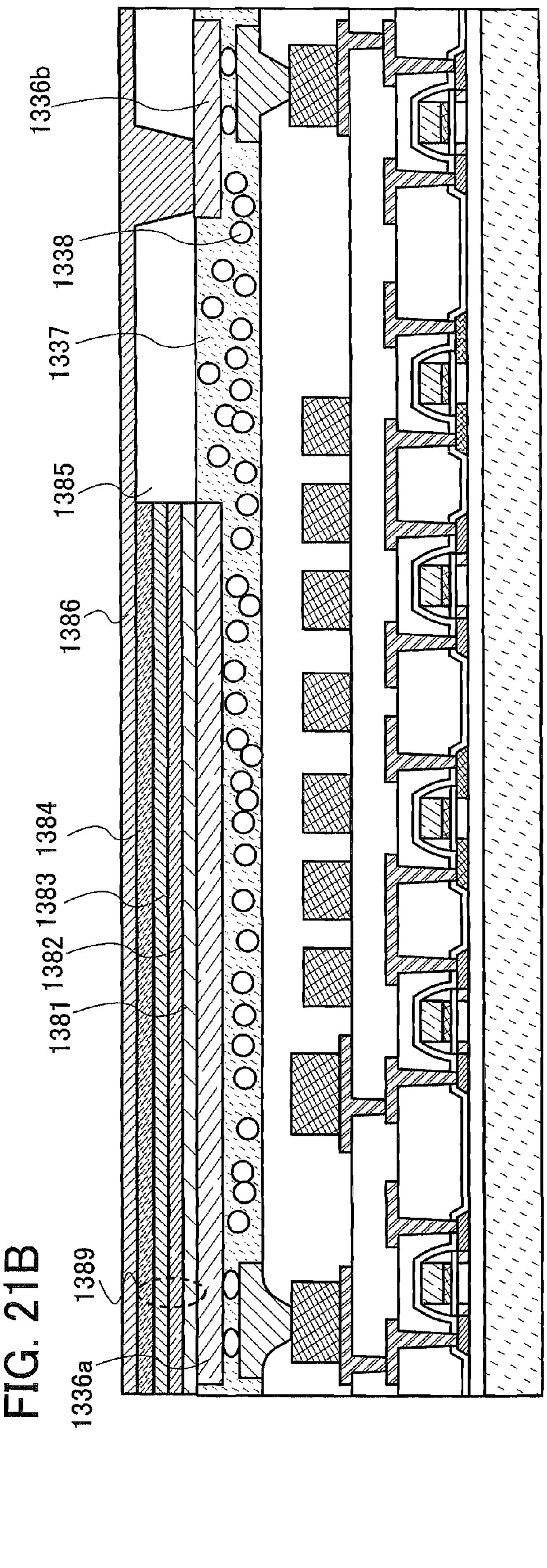


FIG. 21B

FIG. 22A

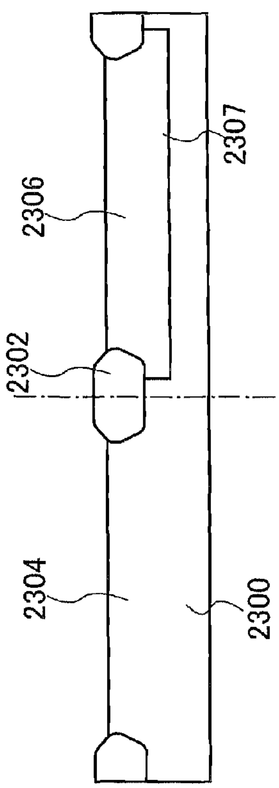


FIG. 22B

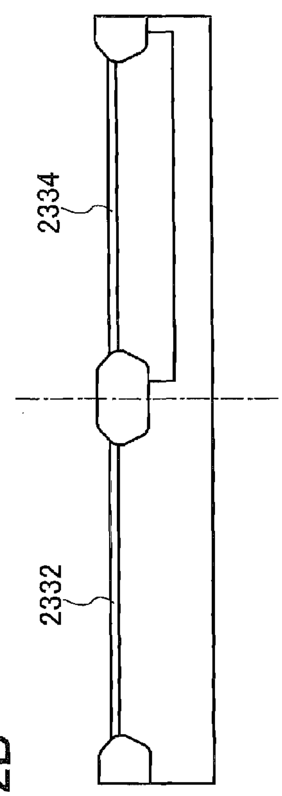
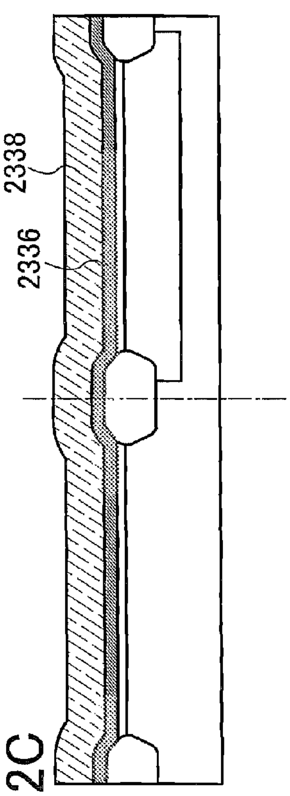


FIG. 22C



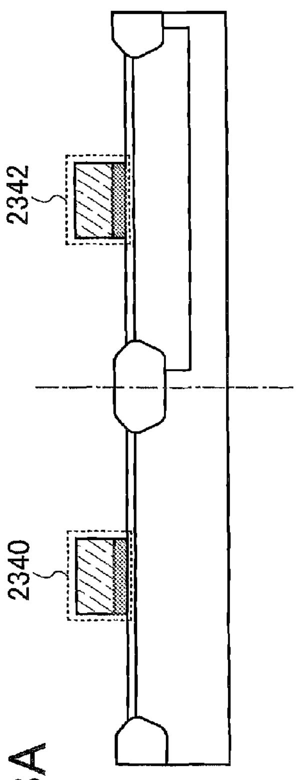


FIG. 23A

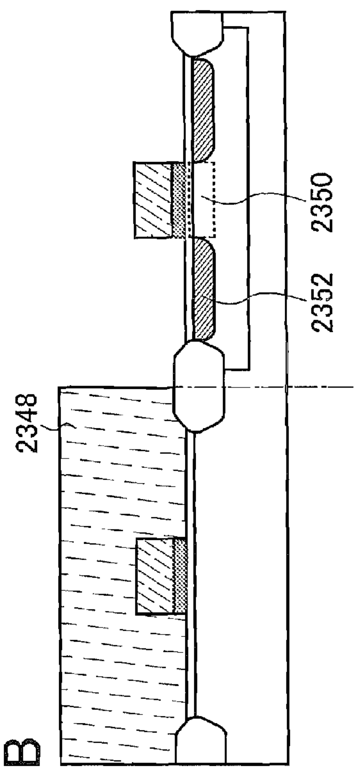


FIG. 23B

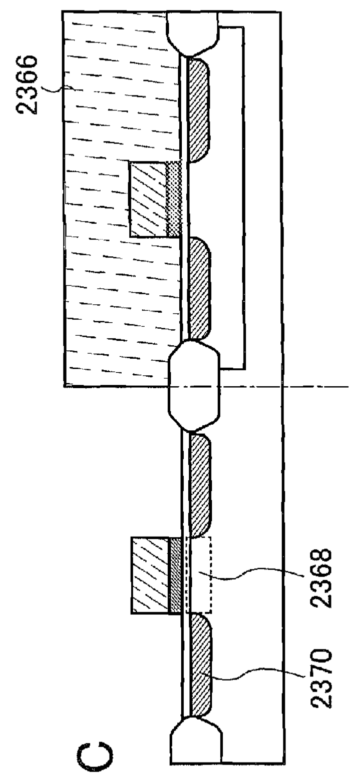


FIG. 23C

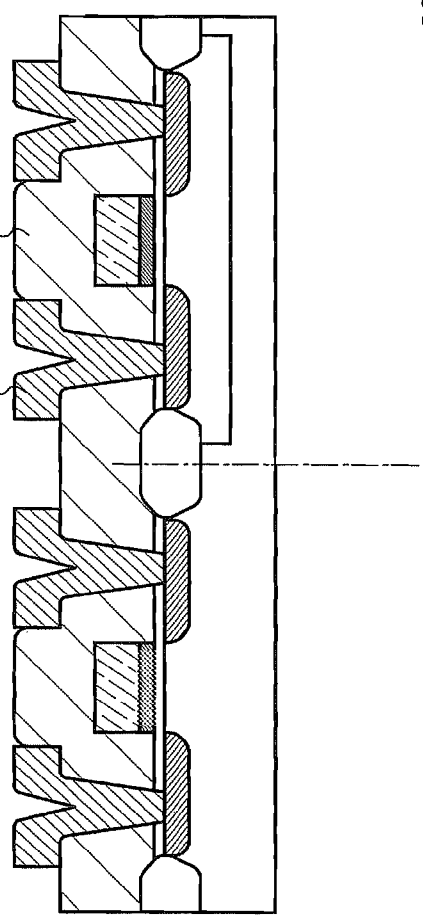


FIG. 24A

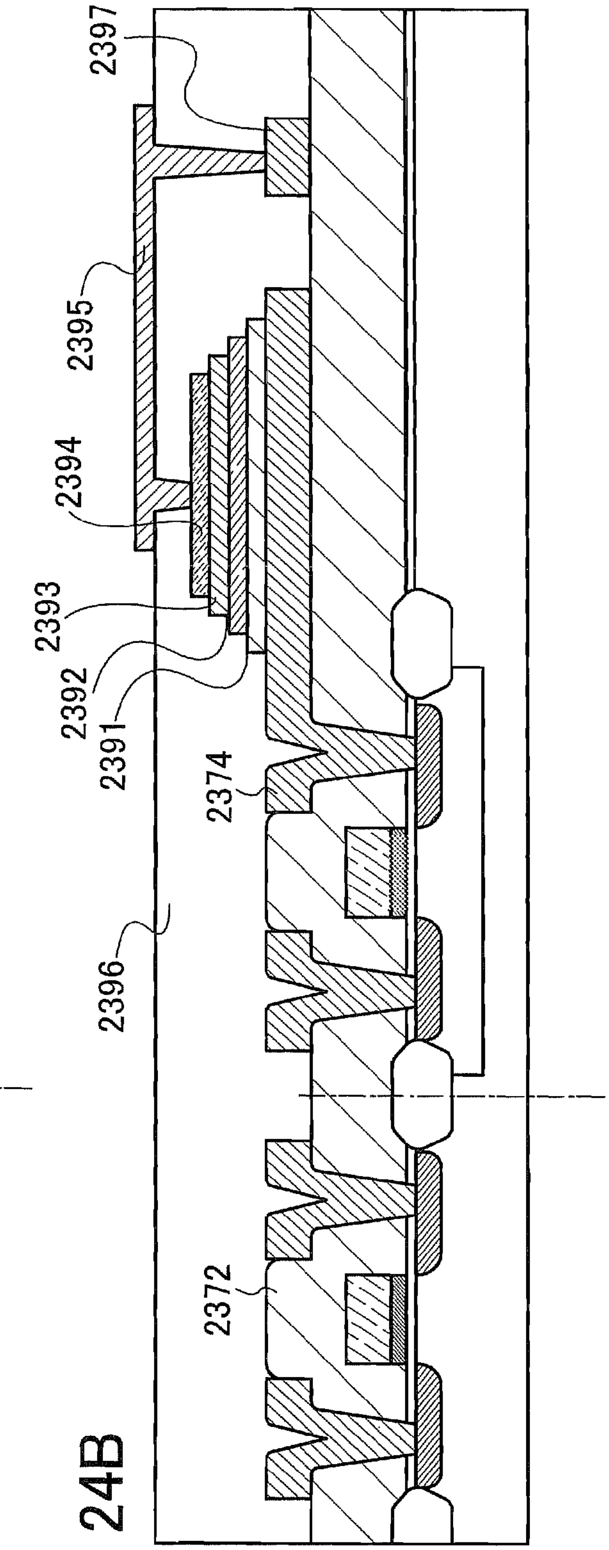


FIG. 24B

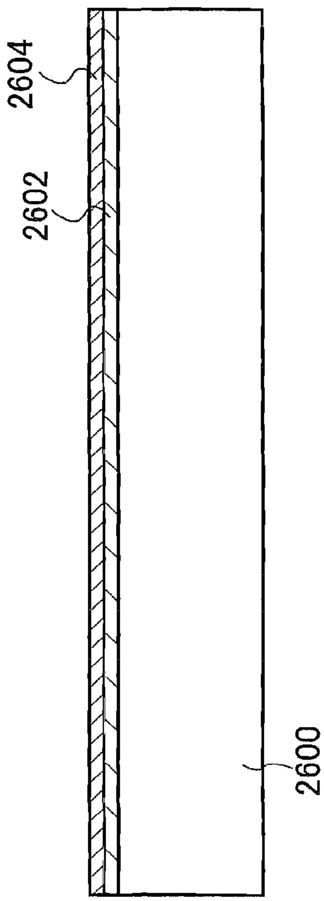


FIG. 25A

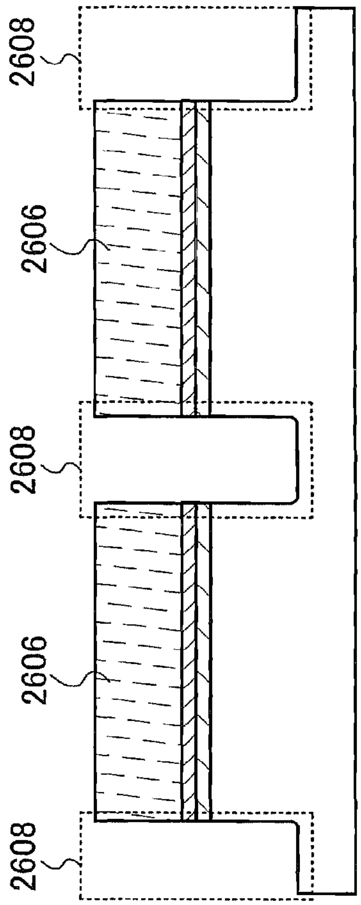


FIG. 25B

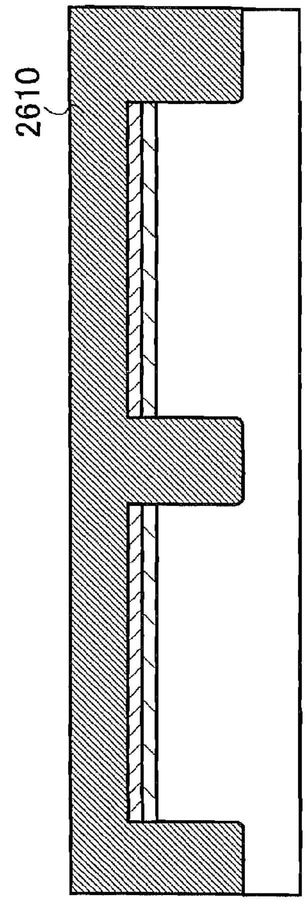


FIG. 25C

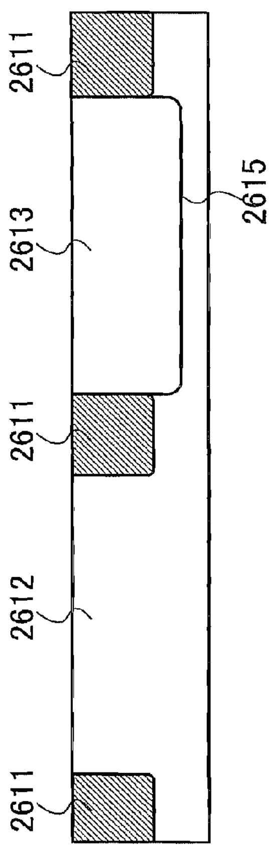


FIG. 26A

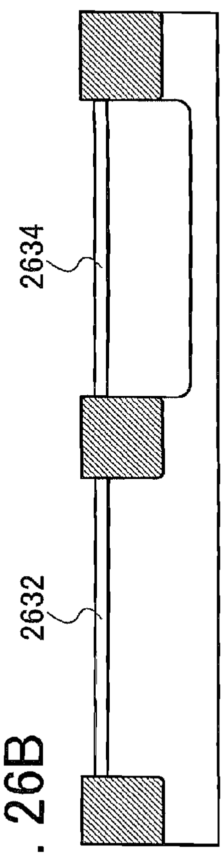


FIG. 26B

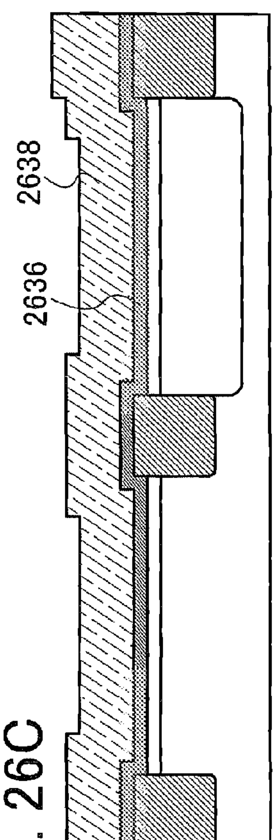


FIG. 26C

FIG. 27A

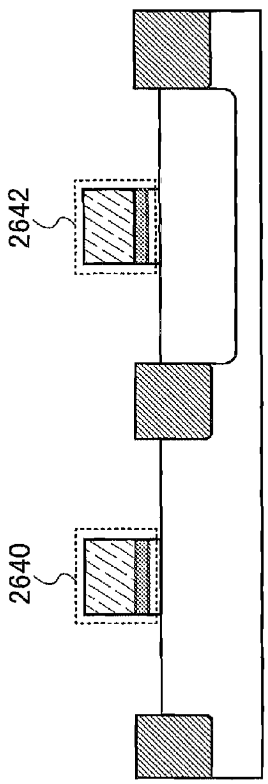


FIG. 27B

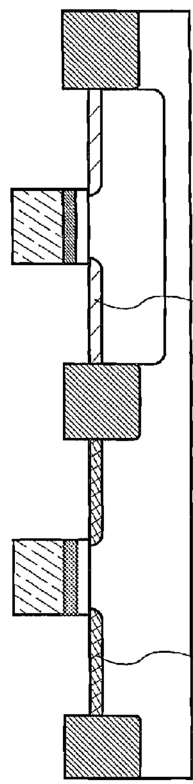


FIG. 27C

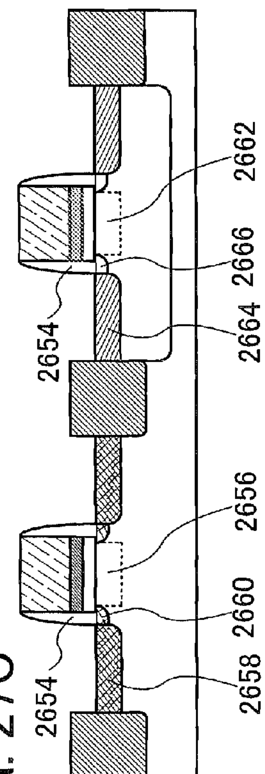


FIG. 28A

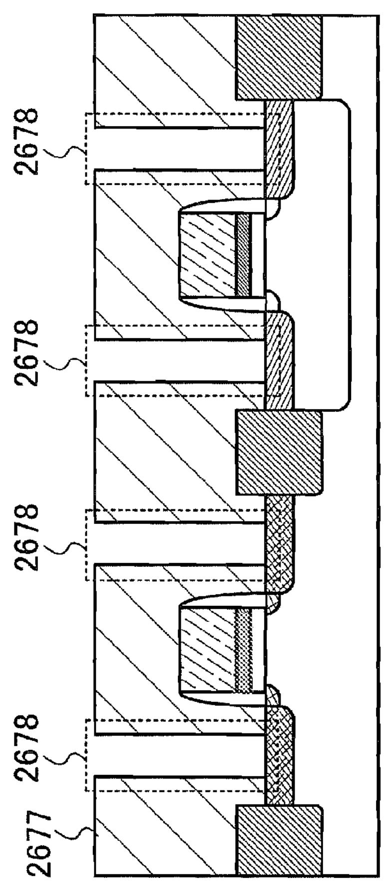


FIG. 28B

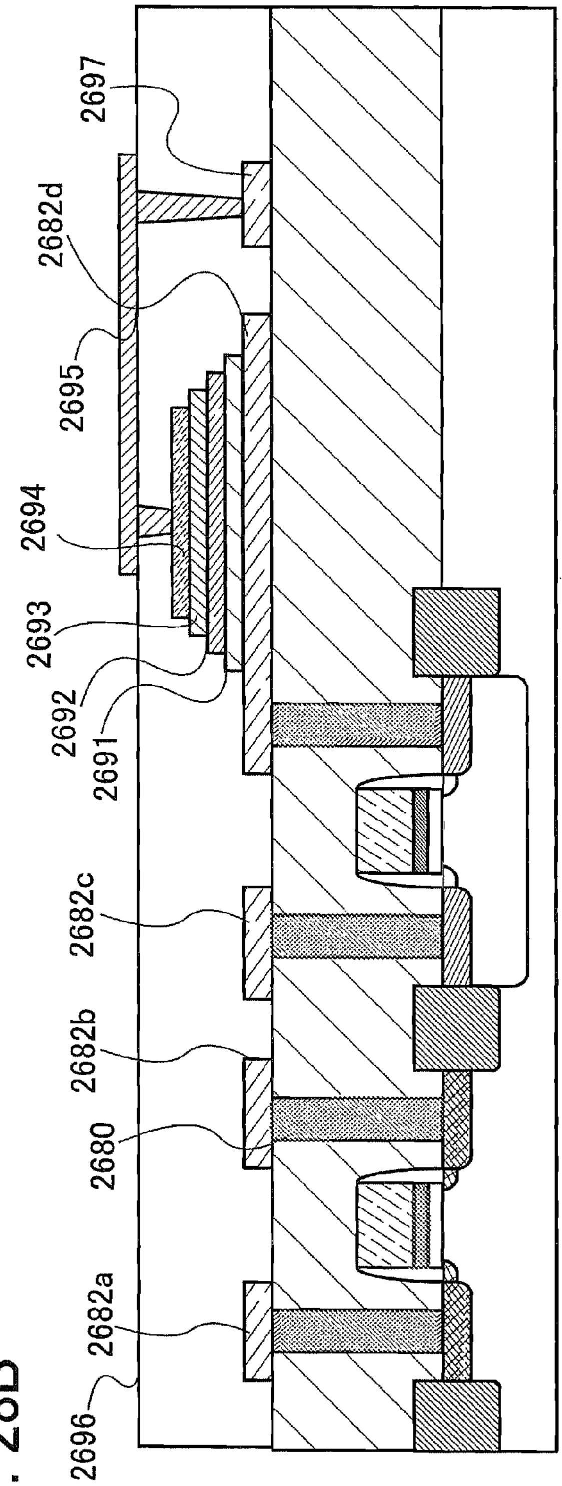


FIG. 29B

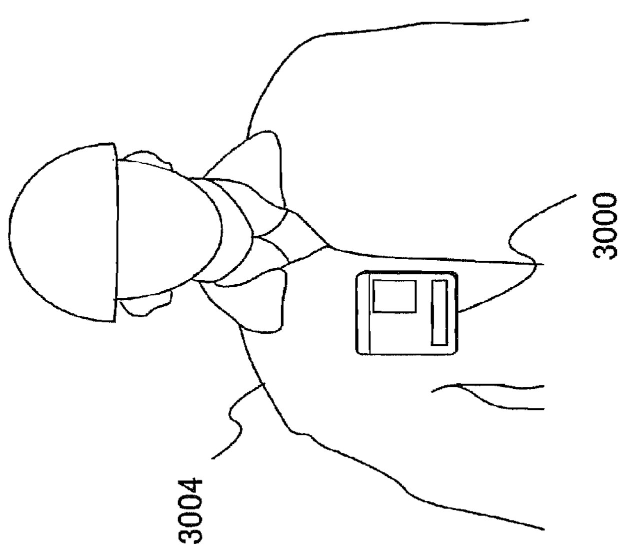


FIG. 29A

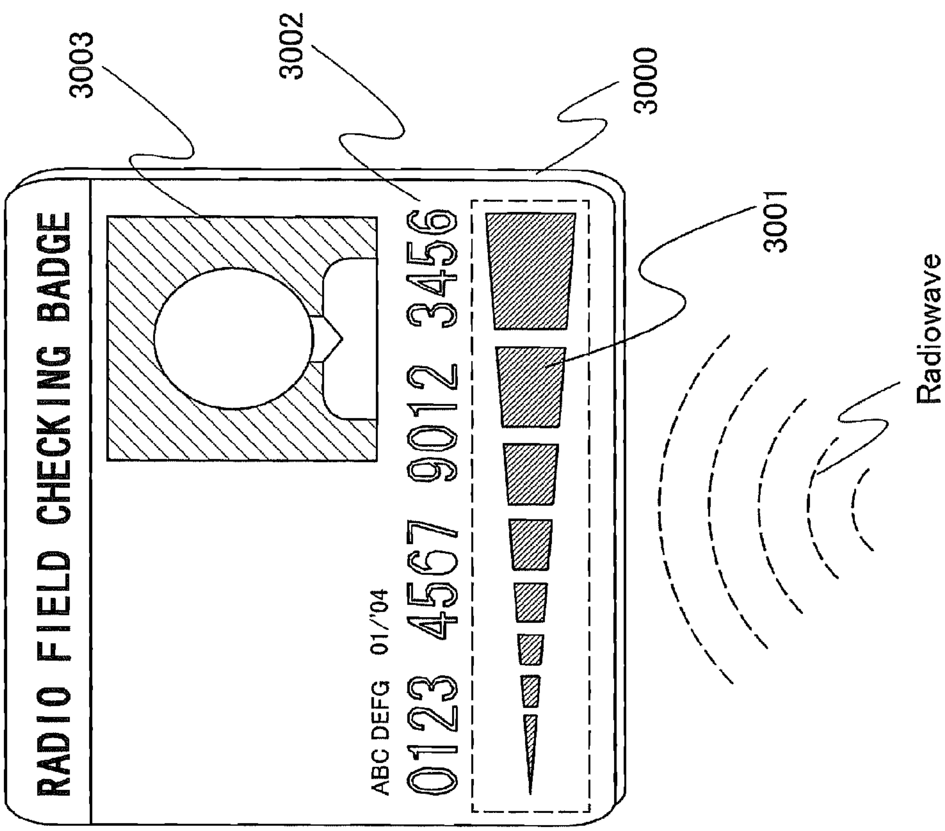


FIG. 30A

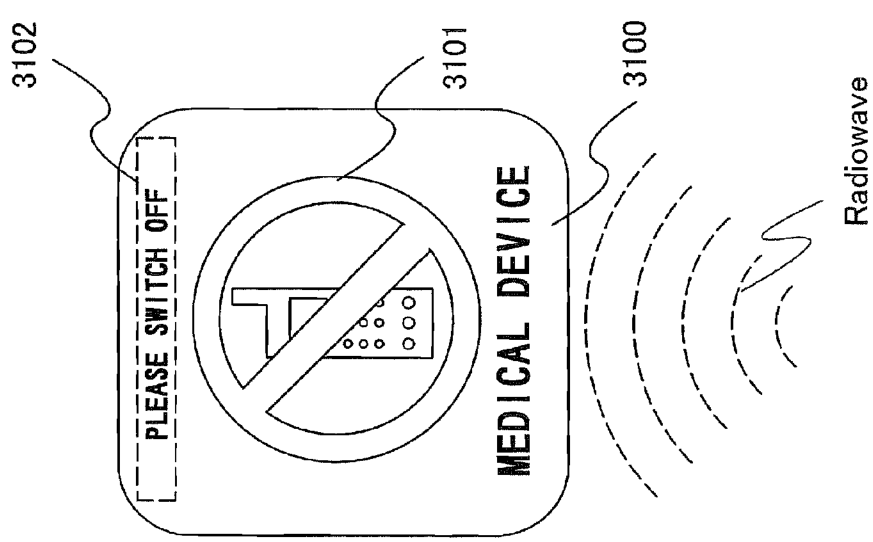


FIG. 30B

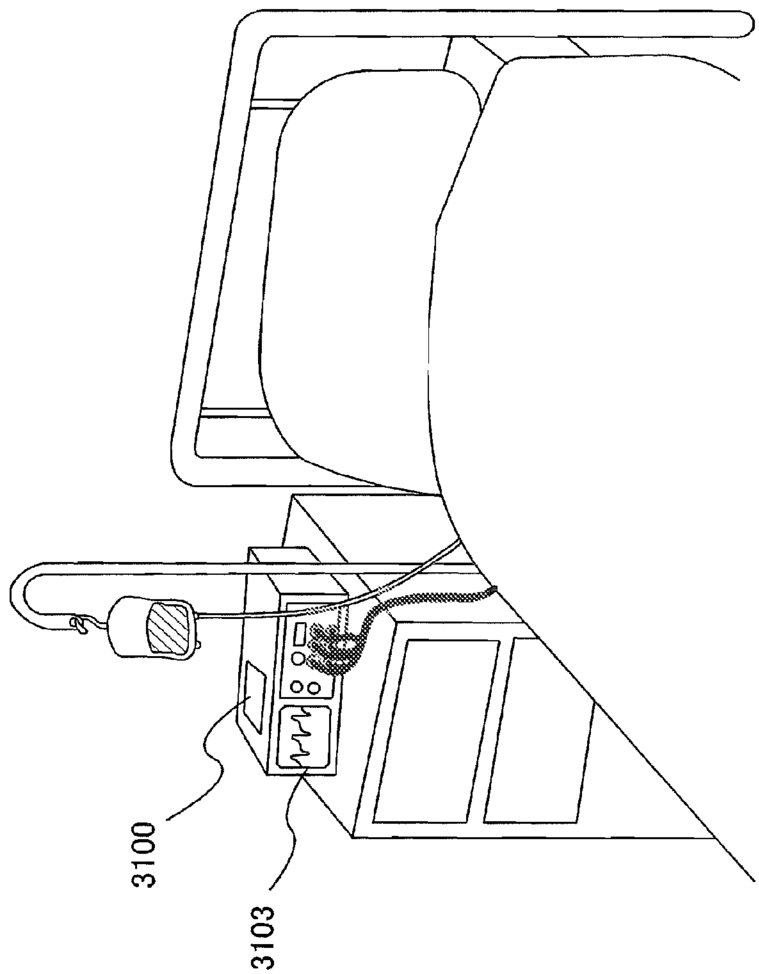


FIG. 31A

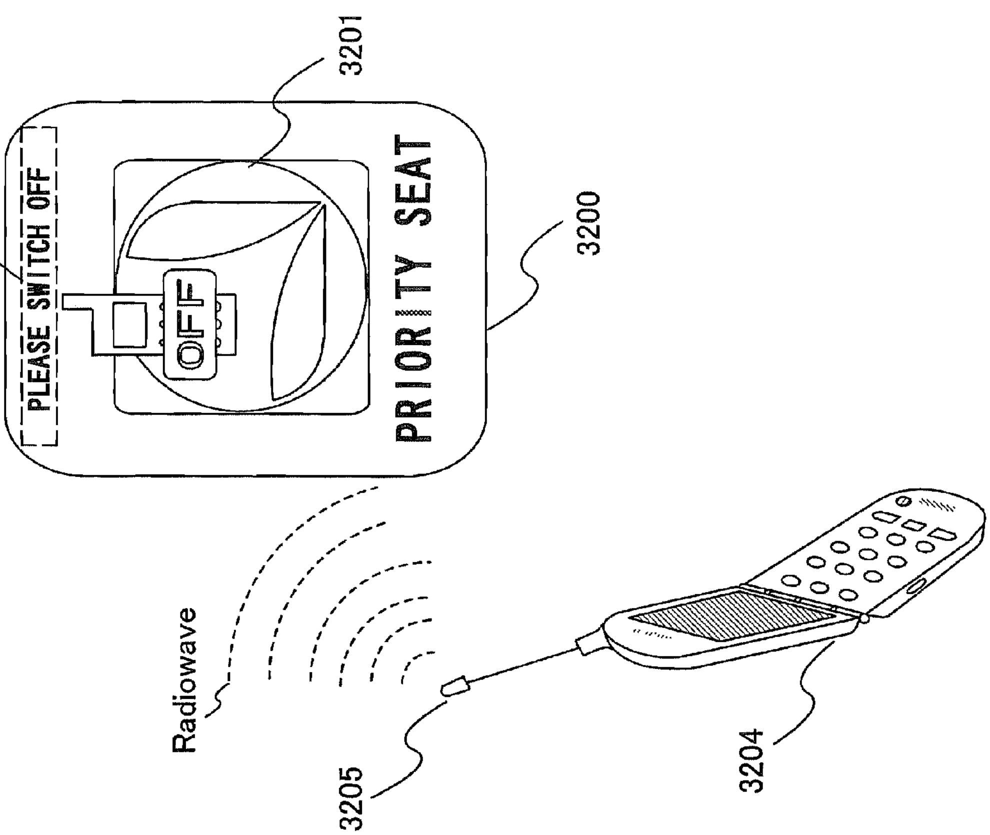


FIG. 31B

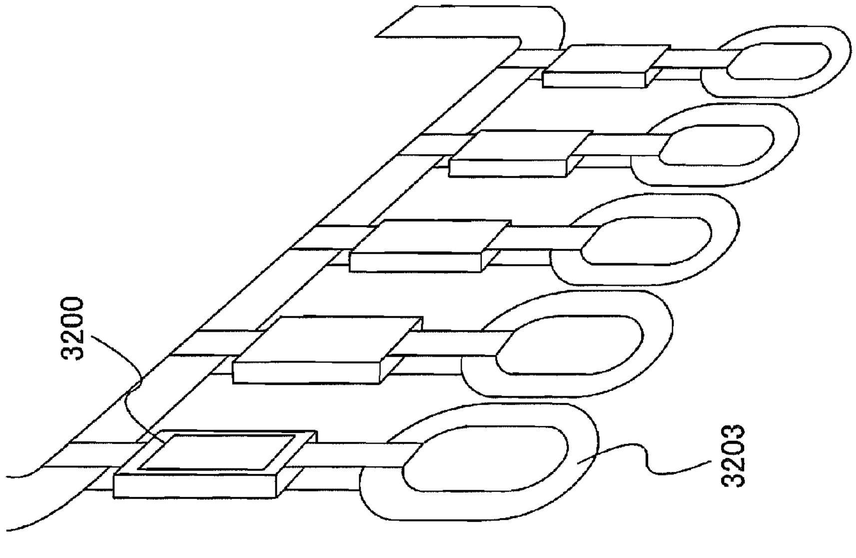


FIG. 32A

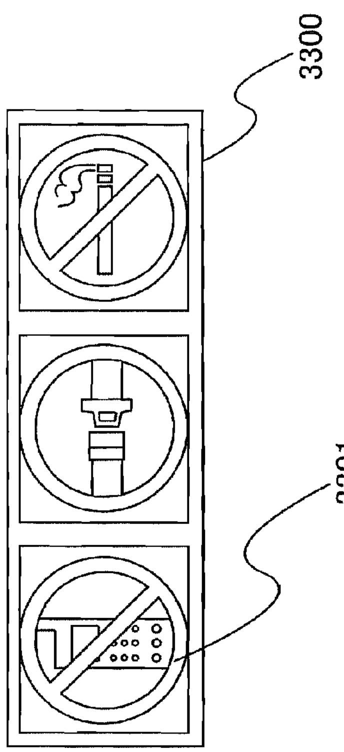


FIG. 32B

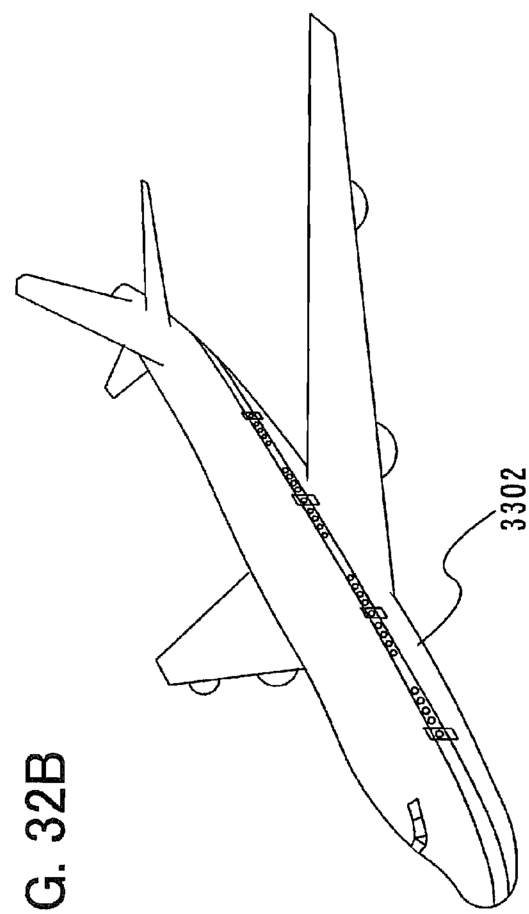


FIG. 32C

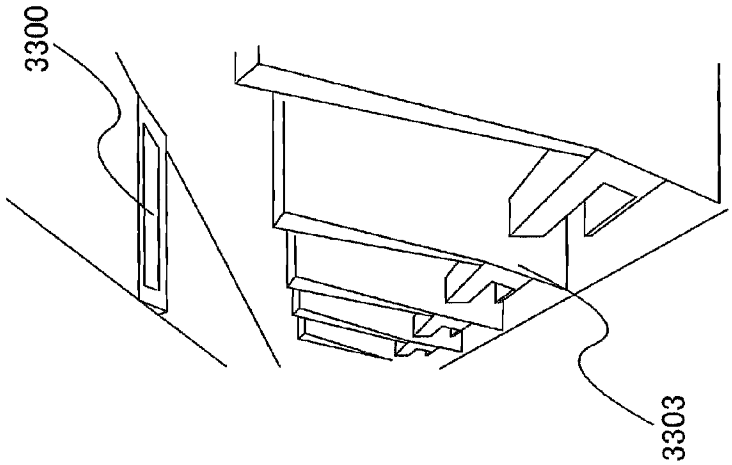


FIG. 33B

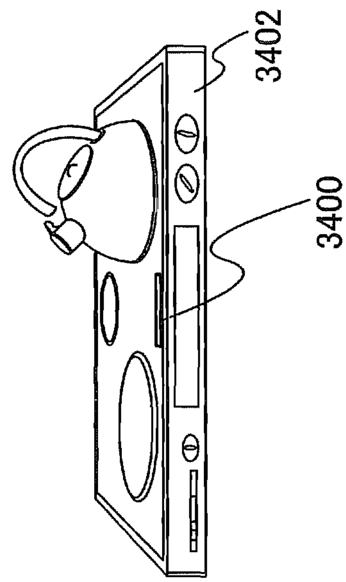
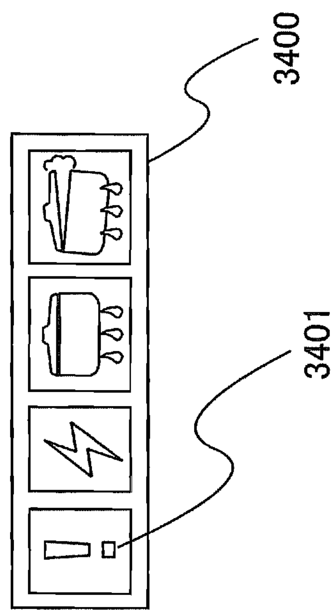


FIG. 33A



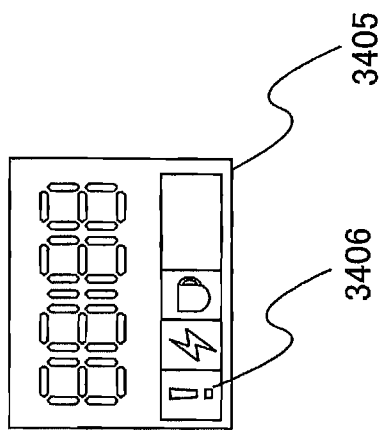


FIG. 34A

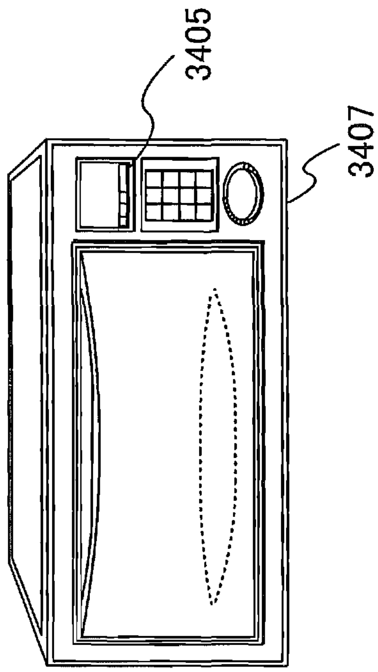


FIG. 34B

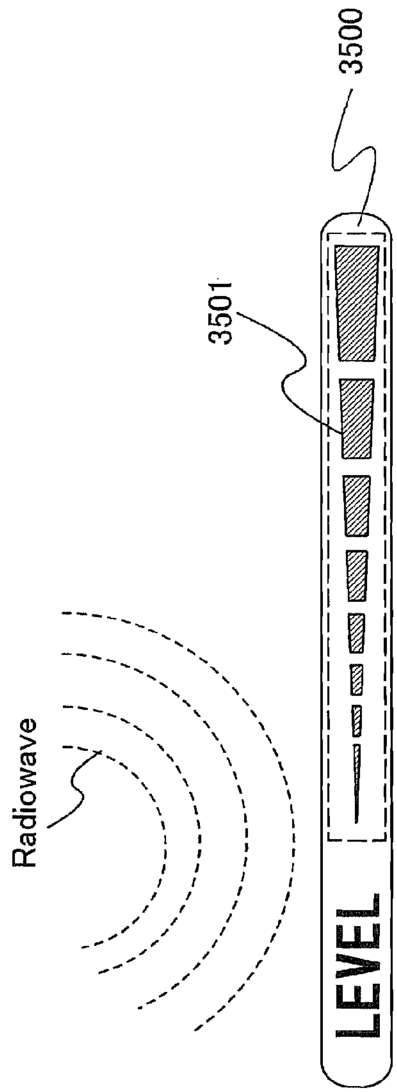


FIG. 35A

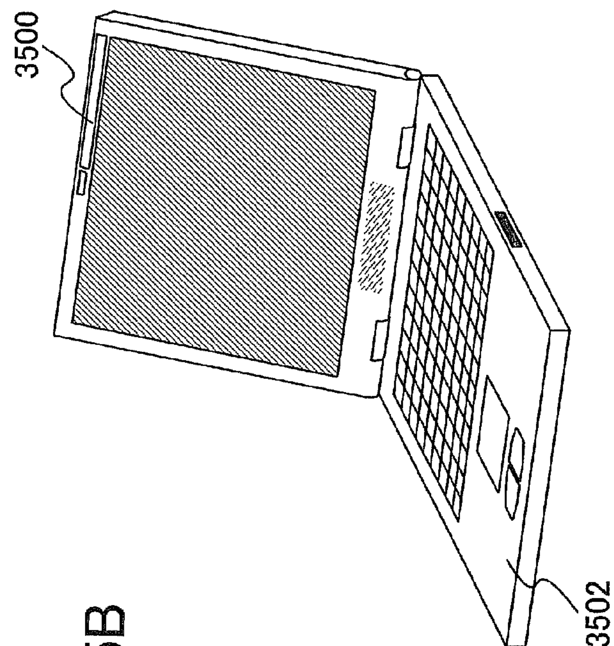


FIG. 35B

FIG. 36A

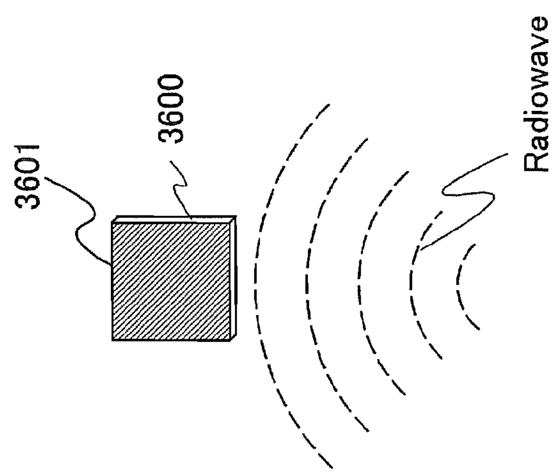


FIG. 36B

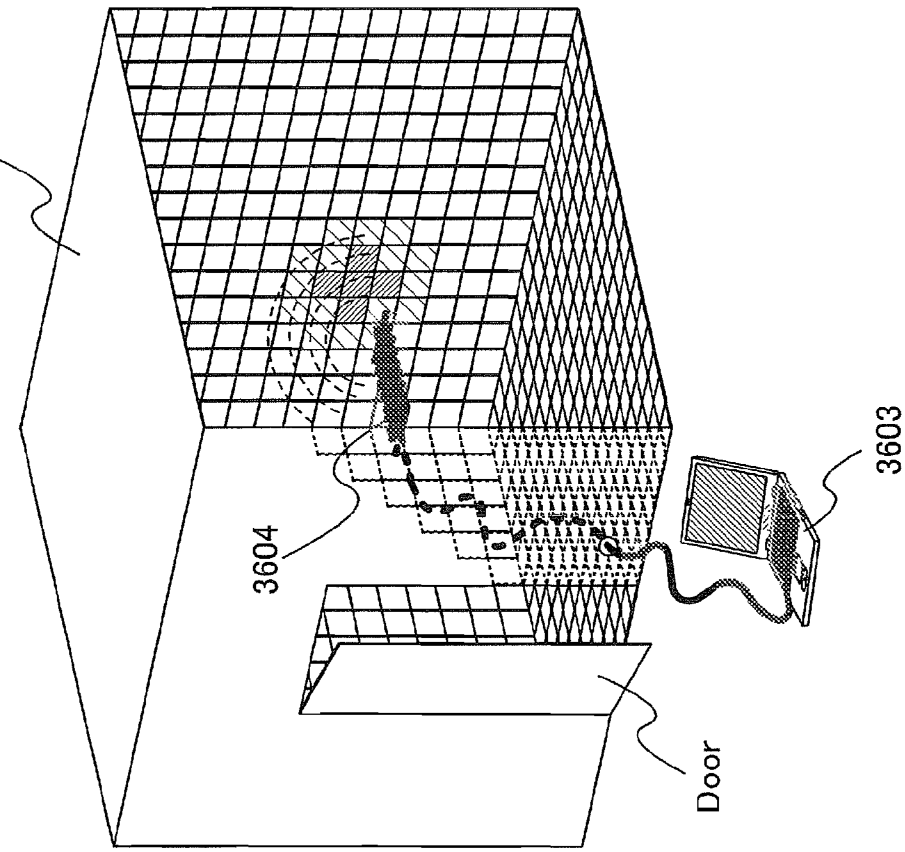


FIG. 37B

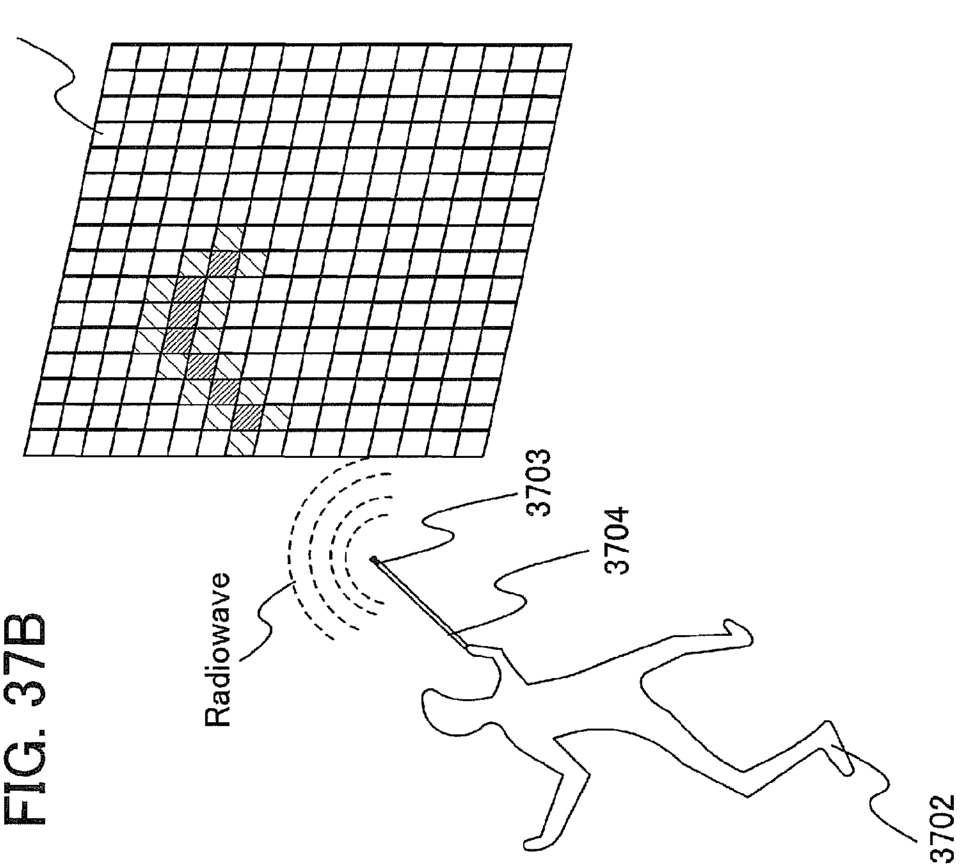


FIG. 37A

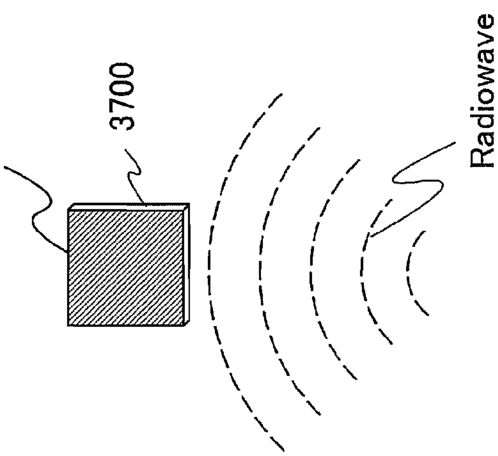
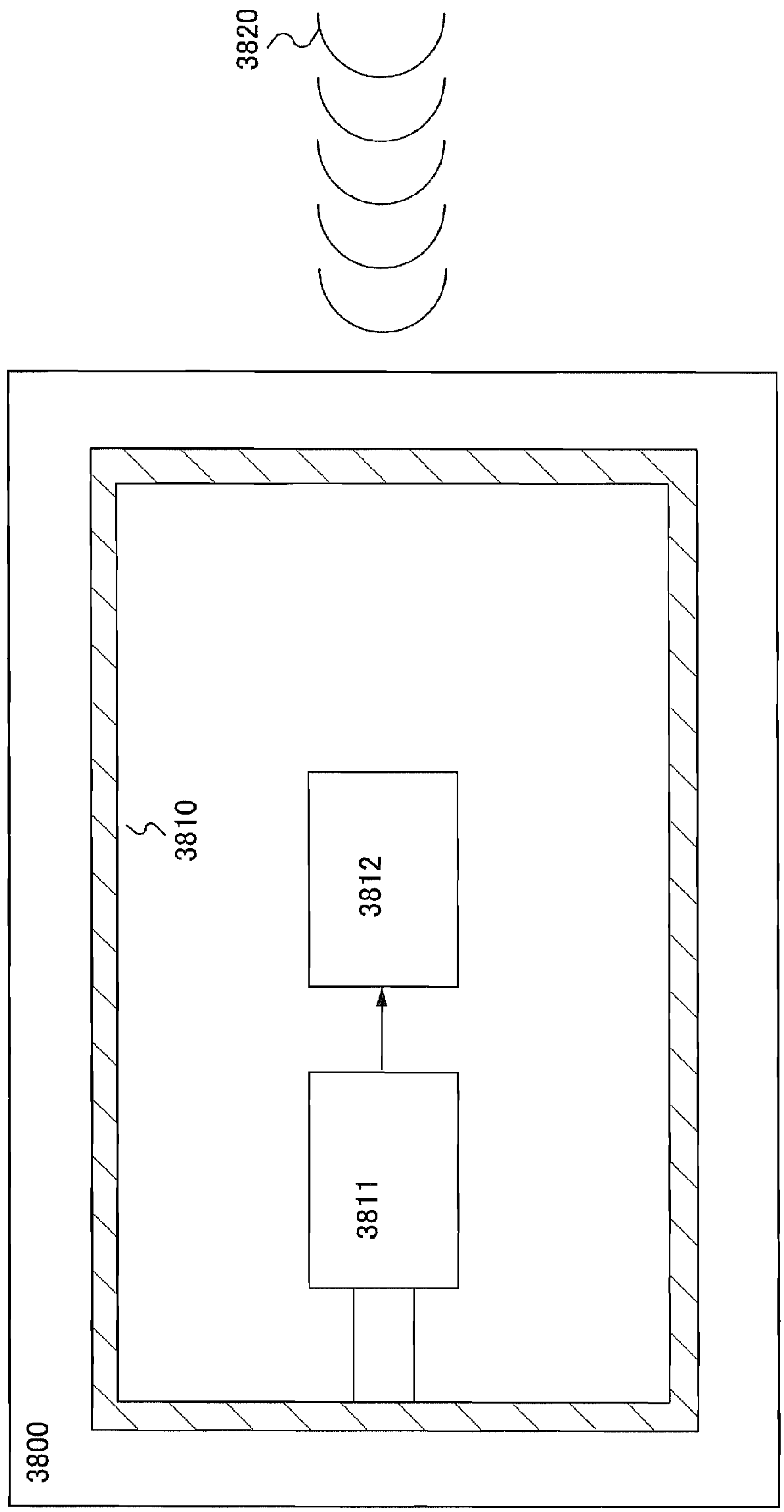


FIG. 38



Prior Art

RADIO FIELD INTENSITY MEASUREMENT DEVICE, AND RADIO FIELD INTENSITY DETECTOR AND GAME CONSOLE USING THE SAME

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to radio field intensity measurement devices which can display radio field intensity of radio signals. In particular, the present invention relates to radio field intensity measurement devices which change color in accordance with radio intensity of a radio signal, utilizing a chromic material, and radio field intensity detectors and amusement devices (such as game consoles, game machines, toys or the like) using the radio field intensity measurement devices.

2. Description of the Related Art

In recent years, wireless devices using radio communication have been spreading due to development of electronics and the coming of an advanced information society, and have been utilized in various fields such as military affairs, medical treatment, communication, education, and commercial transaction. Radio communication using a radiowave as a communication medium takes the maximum advantages of radiowave that information can be transmitted instantly independent from time and distance, and one of the most important bases for human life and industry in modern society.

A radiowave is a kind of electromagnetic waves, and a wave propagated in the air by energy exchange between an electric field and a magnetic field. Since a radiowave cannot be seen, there is a concern that a radiowave emitted from facilities using radiowave and wireless devices may adversely affect human bodies. Thus, there is a need to provide a device which can easily measure radio field intensity of a radiowave emitted from a radio emission device, and display information on the radiowave.

There are various methods for measuring radio field intensity. For example, Reference 1, Japanese Published Patent Application No. 2006-23817, discloses a radio field detector in which an antenna, a rectifier circuit and a lamp are connected and radio field intensity is detected by light intensity of a lamp. Further, Reference 2, Japanese Published Patent Application No. 2001-165973, provides an electromagnetic wave monitor in which an antennal, a storage device, and an informing means are connected, and the informing means is driven by the storage device to measure a radio field intensity.

FIG. **38** is a block diagram illustrating a typical configuration of a radio field intensity measurement device disclosed in Reference 1.

In the radio field intensity measurement device **3800** illustrated in FIG. **38**, a received radiowave **3820** is converted to an induction signal and the induction signal is input to a rectifier circuit **3811**. The rectifier circuit **3811** rectifies the induction signal and supplied power to the lamp **3812**. In other words, electricity which goes up in proportion to the intensity of the received radiowave **3820** is supplied to the lamp, and the intensity of the radiowave appears in the light intensity of the lamp which is turned on.

In the electromagnetic wave monitor in Reference 2, as the informing means, a light-emitting diode, a discharge lamp, or a liquid crystal display device is used.

SUMMARY OF THE INVENTION

However, the radio field intensity measurement device of Reference 1 has a problem of not detecting a weak radiowave, because the weak radiowave emitted over long distance lights the lamp, and thus sufficient power is difficult to secure. Further, in the electromagnetic wave monitor of Reference 2, a weak radiowave is measured to secure power to drive a light-emitting diode, a discharge lamp and a liquid crystal display device as the informing means. However, Reference 2 has a problem in that lighting of the informing means is difficult to be seen when brightness in surroundings is intense e.g., under sunlight.

The present invention has been made in view of the above problems. It is an object of the present invention to provide a radio field intensity measurement device which can measure a weak radiowave, and have a display portion which has a high level of visibility even when brightness in surroundings is intense e.g., under sunlight.

In order to solve the above problems, in accordance with the present invention, a battery is provided as a power source to supply power to a radio field intensity measurement device. The power to drive the radio field intensity measurement device is produced from a received radiowave, and charged in the battery. When a potential of a signal obtained from the received radiowave is higher than an output potential of the battery, the power is stored in the battery. On the other hand, when the potential of the signal obtained from the received radiowave is lower than the output potential of the battery, power produced by the battery is used as power to drive the radio field intensity measurement device.

A radio field intensity measurement device of the present invention employs a thermochromic material or an electrochromic (EC) material as an element to display radio field intensity, and includes a resistor or a voltage application element as a means of changing the color of such a chromic material.

An aspect of the present invention is a radio field intensity measurement device which comprises an antenna to convert a received radiowave to an induction signal; a rectifier circuit configured to output a direct signal by rectifying the induction signal; a battery to be charged by the direct signal; a control circuit configured to compare a potential of the direct signal with an output potential of the battery; an amplifier circuit configured to amplify the direct signal; and a display element which is operated depending on the direct signal amplified by the amplifier circuit. In the radio field intensity measurement device, the control circuit charges the battery when the potential of the direct signal is higher than the output potential of the battery, and when the potential of the direct signal is lower than the output potential of the battery, power of the battery is used as a power source to drive the amplifier circuit.

Another aspect of the present invention is a radio field intensity measurement device which comprises an antenna to convert a received radiowave to an induction signal; a rectifier circuit configured to output a direct signal by rectifying the induction signal; a battery to be charged by the direct signal; a control circuit configured to compare a potential of the direct signal with an output potential of the battery; an amplifier circuit configured to amplify the direct signal; and a display element which is operated depending on the direct signal amplified by the amplifier circuit. In the radio field intensity measurement device, the control circuit charges the battery when the potential of the direct signal is higher than the output potential of the battery, when the potential of the direct signal is lower than the output potential of the battery, power of the battery is used as a power source to drive the amplifier circuit, and a color of the display element is changed in accordance with a magnitude of the direct signal amplified by the amplifier circuit.

Another aspect of the present invention is a radio field intensity measurement device which comprises an antenna to convert a received radiowave to an induction signal; a rectifier circuit configured to output a direct signal by rectifying the induction signal; a battery to be charged by the direct signal; a control circuit configured to compare a potential of the direct signal with an output potential of the battery; an amplifier circuit configured to amplify the direct signal; and a display element which is operated depending on the direct signal amplified by the amplifier circuit. In the radio field intensity measurement device, the control circuit charges the battery when the potential of the direct signal is higher than the output potential of the battery, when the potential of the direct signal is lower than the output potential of the battery, power of the battery is used as a power source to drive the amplifier circuit, and the display element includes a resistance heating element and a thermochromic element.

Another aspect of the present invention is a radio field intensity measurement device which comprises an antenna to convert a received radiowave to an induction signal; a rectifier circuit configured to output a direct signal by rectifying the induction signal; a battery to be charged by the direct signal; a control circuit configured to compare a potential of the direct signal with an output potential of the battery; an amplifier circuit configured to amplify the direct signal; and a display element which is operated depending on the direct signal amplified by the amplifier circuit. In the radio field intensity measurement device, the control circuit charges the battery when the potential of the direct signal is higher than the output potential of the battery, when the potential of the direct signal is lower than the output potential of the battery, power of the battery is used as a power source to drive the amplifier circuit, and the display element includes a resistance heating element and a thermochromic element, and a color of the display element is changed in accordance with a magnitude of the direct signal amplified by the amplifier circuit.

In the present invention, the thermochromic element includes a thermotropic liquid crystal.

Another aspect of the present invention is a radio field intensity measurement device which comprises an antenna to convert a received radiowave to an induction signal; a rectifier circuit configured to output a direct signal by rectifying the induction signal; a battery to be charged by the direct signal; a control circuit configured to compare a potential of the direct signal with an output potential of the battery; an amplifier circuit configured to amplify the direct signal; and a display element which is operated depending on the direct signal amplified by the amplifier circuit. In the radio field intensity measurement device, the control circuit charges the battery when the potential of the direct signal is higher than the output potential of the battery, when the potential of the direct signal is lower than the output potential of the battery, power of the battery is used as a power source to drive the amplifier circuit, and the display element includes a voltage application element and an electrochromic element.

Another aspect of the present invention is a radio field intensity measurement device which comprises an antenna to convert a received radiowave to an induction signal; a rectifier circuit configured to output a direct signal by rectifying the induction signal; a battery to be charged by the direct signal; a control circuit configured to compare a potential of the direct signal with an output potential of the battery; an amplifier circuit configured to amplify the direct signal; and a display element which is operated depending on the direct signal amplified by the amplifier circuit. In the radio field intensity measurement device, the control circuit charges the battery when the potential of the direct signal is higher than the output potential of the battery, when the potential of the direct signal is lower than the output potential of the battery, power of the battery is used as a power source to drive the amplifier circuit, and the display element includes a voltage application element and an electrochromic element, and a color of the display element is changed in accordance with a magnitude of the direct signal amplified by the amplifier circuit.

In addition, in the present invention, the electrochromic element includes a metal oxide.

The battery of the present invention is a lithium battery, a lithium polymer battery, a lithium ion battery, a nickel hydride battery, a nickel cadmium battery, an organic radical battery, a lead-acid battery, an air secondary battery, a nickel zinc battery, a silver zinc battery, or a capacitor.

The capacitor of the present invention is an electric double layer capacitor.

The radio field intensity detector of the present invention is attached to an object to detect a radiowave.

An amusement device of the present invention comprises a plate-like radio field intensity detector attached with the radio field intensity detector and a radiowave emitter, and a color of the plate-like radio field intensity detector is changed by using a radiowave emitted from the radiowave emitter.

It is to be noted that description "be connected" in the present invention indicates electrical connection. Therefore, in structures disclosed in the present invention, another element capable of electrical connection (e.g., a switch, a transistor, a capacitor, an inductor, a resistor, a diode, or the like) may be interposed between elements having a predetermined connection relation.

The present invention provides a radio field intensity measurement device which can measure a weak radiowave from a long distance. Further, the present invention provides a radio field intensity measurement device which has a high level of visibility even when brightness in surroundings is intense e.g., under sunlight.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is a view describing Embodiment Mode 1;

FIG. **2** is a view describing Embodiment Mode 1;

FIGS. **3**A to **3**E are views describing Embodiment Mode 1;

FIG. **4** is a view describing Embodiment Mode 1;

FIG. **5** is a view describing Embodiment Mode 1;

FIG. **6** is a view describing Embodiment Mode 1;

FIGS. **7**A and **7**B are views describing Embodiment Mode 1;

FIG. **8** is a view describing Embodiment Mode 1;

FIG. **9** is a view describing Embodiment Mode 1;

FIG. **10** is a view describing Embodiment Mode 1;

FIG. **11** is a view describing Embodiment Mode 1;

FIG. **12** is a view describing Embodiment Mode 1;

FIGS. **13**A and **13**B are views describing Embodiment Mode 2;

FIGS. **14**A to **14**C are views describing Embodiment Mode 2;

FIGS. **15**A and **15**B are views describing Embodiment Mode 2;

FIG. **16** is a view describing Embodiment Mode 2;

FIGS. **17**A to **17**D are views describing Embodiment 1;

FIGS. **18**A to **18**C are views describing Embodiment 1;

FIGS. **19**A and **19**B are views describing Embodiment 1;
FIGS. **20**A and **20**B are views describing Embodiment 1;
FIGS. **21**A and **21**B are views describing Embodiment 1;
FIGS. **22**A to **22**C are views describing Embodiment 2;
FIGS. **23**A to **23**C are views describing Embodiment 2;
FIGS. **24**A and **24**B are views describing Embodiment 2;
FIGS. **25**A to **25**C are views describing Embodiment 3;
FIGS. **26**A to **26**C are views describing Embodiment 3;
FIGS. **27**A to **27**C are views describing Embodiment 3;
FIGS. **28**A and **28**B are views describing Embodiment 3;
FIGS. **29**A and **29**B are views describing Embodiment 4;
FIGS. **30**A and **30**B are views describing Embodiment 4;
FIGS. **31**A and **31**B are views describing Embodiment 4;
FIGS. **32**A to **32**C are views describing Embodiment 4;
FIGS. **33**A and **33**B are views describing Embodiment 4;
FIGS. **34**A and **34**B are views describing Embodiment 4;
FIGS. **35**A and **35**B are views describing Embodiment 4;
FIGS. **36**A and **36**B are views describing Embodiment 4;
FIGS. **37**A and **37**B are views describing Embodiment 5; and

FIG. **38** is a view describing an object of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Embodiment Modes

Embodiment Modes of the present invention will be explained below with reference to the accompanied drawings. It is easily understood by those skilled in the art that modes and details disclosed herein can be modified in various ways without departing from the spirit and the scope of the present invention. Therefore, the present invention should not be interpreted as being limited to the description of the embodiment modes to be given below. It is to be noted that, in the present invention explained below, there is a case that similar portions or portions having a similar function are denoted by the same reference numerals through the drawings.

Embodiment Mode 1

Embodiment Mode 1 will describe a structure of a radio field intensity measurement device of the present invention.

FIG. **1** is a block diagram of a radio field intensity measurement device of the present invention. The radio field intensity measurement device **100** includes an antenna **110**, a rectifier circuit **111**, a control circuit **112**, a battery **113**, an amplifier circuit **114** and a display element **115**. Note that the rectifier circuit **111**, the control circuit **112** and the amplifier circuit **114** are collectively referred to as a signal processing circuit **120** for simple description.

FIG. **2** is a block diagram in which the antenna **110** receives a received radiowave **302** from a radiowave source **301**. In FIG. **2**, the radiowave received by the antenna **110** is converted into an induction signal and input into the rectifier circuit **111**. The rectifier circuit **111** converts the induction signal to a direct signal and outputs the direct signal. In addition, the direct signal output from the rectifier circuit **111** is input into the battery **113** through the control circuit **112**. Meanwhile, the direct signal output from the rectifier circuit **111** is amplified by the amplifier circuit **114** and input into the display element **115**. The display element **115** changes color in accordance with the direct signal amplified by the amplifier circuit **114**.

The rectifier circuit **111**, for example as illustrated in FIG. **4**, a diode **503**, a diode **504**, and a capacitor **505**, and an induction signal received by the antenna **110** is half-wave rectified by the diode **504** and smoothed by the capacitor **505**. The direct signal which is output from the rectifier circuit **111** and which is half-wave rectified and smoothed is supplied to the control circuit **112**.

The control circuit **112**, for example as illustrated in FIG. **5**, includes a diode **604**, a diode **605**, a voltage comparison circuit **601**, a switch **602** and a switch **603**.

The voltage comparison circuit **601** compares an output potential of the battery **113** with a potential of a direct signal output from the rectifier circuit **111**. When the potential of the direct signal output from the rectifier circuit **111** is sufficiently higher than the output potential of the battery **113**, the voltage comparison circuit **601** turns the switch **602** on and the switch **603** off. Thus, current flows to the battery **113** from the rectifier circuit **111** through the diode **604** and the switch **602**. On the other, hand, when the potential of the direct signal output from the rectifier circuit **111** is not sufficiently higher than the output potential of the battery **113**, the voltage comparison circuit **601** turns the switch **602** off and the switch **603** on. At this time, when the potential of the direct signal output from the rectifier circuit **111** is higher than the output potential of the battery **113**, no current flows to the diode **605**. On the other hand, when the potential of the direct signal output from the rectifier circuit **111** is lower than the output potential of the battery **113**, current flows to the amplifier circuit **114** from the battery **113** through the switch **603** and the diode **605**.

Note that the control circuit is not limited to the example in Embodiment Mode 1, and may employs any mode.

As a switch employed in this specification, a transistor (e.g., a bipolar transistor or a MOS transistor), a diode (e.g., a PN diode, a PIN diode, a Schottky diode, a MIM (Metal Insulator Metal) diode, a MIS (Metal Insulator Semiconductor) diode, or a diode-connected transistor), a thyristor, or the like can be used. Alternatively, a logic circuit combining such elements can be used as a switch.

FIG. **6** illustrates an example of the voltage comparison circuit **601**.

By the voltage comparison circuit **601**, a voltage output from the battery **113** is divided by resistors **701** and **702**, and a voltage output from the rectifier circuit **111** is divided by resistors **703** and **704**. Then, the voltages divided by the resistors are input to a comparator **705**. Buffers **706** and **707** of inverter topologies are connected in series with an output of the comparator **705**. Then, an output of the buffer **706** is input to a control terminal of the switch **603**, and an output of the buffer **707** is input to a control terminal of the switch **602**, so that on/off of the switches **602** and **603** in FIG. **6** is controlled. Note that when H-level signals are input to the control terminals of the switches **602** and **603**, the switches **602** and **603** are turned on, whereas when L-level signals are input, the switches **602** and **603** are turned off.

By regulating a voltage input to the comparator **705** by dividing an incoming voltage with the resistors, it becomes possible to control the timings for turning the switch **602** on and turning the switch **603** off at a point when the voltage output from the rectifier circuit becomes higher than the voltage output from the battery **113** by a certain level. Similarly, it becomes possible to control the timings for turning the switch **602** off and turning the switch **603** on at a point when the voltage output from the rectifier circuit becomes lower than the voltage output from the battery **113** by a certain level.

Note that the voltage comparison circuit is not limited to this example in this embodiment mode, and may employ any mode.

With reference to the timing chart of FIG. **9**, operation of the voltage comparison circuit is described. A first waveform **1001** is a change of a potential after the division by the resistors **701** and **702** in FIG. **6**. A second waveform **1002** is a change of a potential after the division by the resistors **703** and **704** in FIG. **6**. A first signal **1010** is a control signal which is output from the comparator **705** and is input to the buffer **706** in FIG. **6**. A second signal **1011** is a control signal which is output from the buffer **706** and is input to a control terminal of the switch **603** in FIG. **6**. A third signal **1012** is a control signal which is output from the buffer **707** and is input to a control terminal of the switch **602** in FIG. **6**. For simple description, a signal which is input to the rectifier circuit **111** from the antenna **110** before rectification is denoted by a waveform before rectification **1020** (a waveform of an induction signal).

In FIG. **9**, when the potential of the first waveform **1001** is higher than that of the second waveform **1002**, i.e., when the amplitude of the waveform before rectification which is a signal before rectification is large, the first signal **1010** is at a high potential level (hereinafter, abbreviated as H), the second signal **1011** at a low potential level (hereinafter, abbreviated as L), and the third signal **1012** is H. Accordingly, the switch **603** to which L of the second signal **1011** is input is turned off, and the switch **602** to which H of the third signal **1012** is input is turned on. Thus, the battery **113** is charged as illustrated in FIG. **10**. The period in which the battery **113** is charged is regarded as a charge period **1030**, and during this charge period **1030**, the amplifier circuit **114** uses power output from the rectifier circuit **111**.

In FIG. **9**, when the potential of the first waveform **1001** is lower than that of the second waveform **1002**, i.e., the amplitude of the waveform before rectification **1020** which is a signal before rectification, is small, the first signal **1010**, the second signal **1011** and the third signal **1012** are L, H, and L respectively. Accordingly, the switch **603** to which H of the second signal **1011** is input is turned on, and the switch **602** to which L of the third signal **1012** is input is turned off. Thus, the battery **113** is discharged as illustrated in FIG. **11**. The period in which the battery **113** is discharged is regarded as a discharge period **1031**, and during this discharge period **1031**, the amplifier circuit **114** uses power output from the battery **113**.

Therefore, the amplifier circuit **114** receives power either in the charge period **1030** or the discharge period **1031**.

Non-limiting examples of the battery **113** includes secondary batteries such as a lithium ion battery, a lithium secondary battery, a nickel metal hydride battery, a nickel cadmium battery, and an organic radical battery. Alternatively, a capacitor having large capacity may be used.

Note that the term "charge" indicates that current flows to the battery **113**, so that power is stored in the battery **113**. Specifically, in a secondary battery, "charge" means that electric energy input to the battery **113** is converted to chemical energy to be stored. On the other hand, the term "discharge" indicates that chemical energy in the battery **113** is converted to electric energy to be output.

A capacitor having large capacity which can be used as the battery **113** of the present invention is preferably a capacitor having electrodes whose opposed areas are large. In particular, it is preferable to use an electric double layer capacitor which is formed from an electrode material having a large specific surface area such as activated carbon, fullerene, or a carbon nanotube. A capacitor has a simpler structure than a battery. Further, a capacitor can be easily formed to be thin and formed by stacking layers. An electric double layer capacitor has a function of storing power and will not deteriorate so much even after it is charged and discharged a large number of times. Further, the electric double layer capacitor has an excellent property in that it can be charged rapidly.

For the display element **115**, an element including a material exhibiting a chromism phenomenon, such as a thermochromic material or an electrochromic material, can be used, but not limited to such an element.

Next, with reference to the timing chart of FIG. **12**, operation of the radio field intensity measurement device is described. A first waveform **1201** is a potential change of a direct signal which is rectified in the rectifier circuit **111** and is input to the amplifier circuit **114** in FIG. **2**. A second waveform **1202** is a potential change of a signal which is output from the control circuit **112** and is input to the amplifier circuit **114** as power in FIG. **2**. Note that the second waveform **1202** is the same as the second waveform **1002** in FIG. **9**. A third waveform **1203** is a potential change of voltage, which is obtained by amplifying the first waveform **1201** input into the amplifier circuit **114** in FIG. **2** with the amplifier circuit **114** to be input to the display element **115**. For simple description, a signal which is input to the rectifier circuit **111** from the antenna **110** before rectification is denoted by a waveform before rectification **1220** (a waveform of an induction signal). A period in which the waveform before rectification **1220** is small is denoted by a weak radiowave period **1221**, and a period in which the waveform before rectification **1220** is large is denoted by a strong radiowave period **1222**, and the minimum operation voltage of the display element **115** is denoted by reference numeral **1223**. The minimum operation voltage is a minimum voltage at which the display element **115** can cause color change which is visible to human eyes.

In FIG. **12**, in the weak radiowave period **1221**, the first waveform **1201** is amplified as shown by the third waveform **1203**. In addition, also in the strong radiowave period **1222**, the first waveform **1201** is amplified as shown by the third waveform **1203**. In this case, the ratio of increase from the first waveform **1201** to the third waveform (V_2/V_1) is referred to as an amplification ratio. Note that the amplifier circuit **114** may have such an amplification ratio that the third waveform after amplification exceeds the minimum operation voltage **1223**.

Therefore, the display element **115** can operate either in the weak radiowave period **1221** or the strong radiowave period **1222**.

Then, FIG. **7**A schematically illustrates of a radio field intensity measurement device of the present invention.

The radio field intensity measurement device illustrated in FIG. **7**A includes an antenna **810**, a signal processing circuit **811**, a battery **812** and a display element **813** over a substrate **801**. The antenna **810** includes a connection terminal **820** and a connection terminal **821**. The connection terminals **820** and **821** of the antenna **810** are both connected to the signal processing circuit **811**.

As a transistor which can be used for the signal processing circuit **811**, various types of transistors can be applied without being limited to particular types of transistors. Accordingly, a thin film transistor (TFT) using a non-single crystalline semiconductor film typified by amorphous silicon or polycrystalline silicon, a transistor formed by using a semiconductor substrate or an SOI substrate, a MOS transistor, a junction transistor, a bipolar transistor, a transistor using a compound semiconductor such as ZnO or a-InGaZnO, a transistor using an organic semiconductor or a carbon nanotube, or other transistors can be applied. Note that a non-single crystalline semiconductor film may include hydrogen or halogen.

In addition, various types of substrates can be employed as the substrate **801** without particular limitations. Accordingly, for example, a single crystalline substrate, an SOI substrate, a glass substrate, a quartz substrate, a plastic substrate, a paper substrate, a cellophane substrate, a stone substrate, or the like can be used. In addition, the signal processing circuit **811** may be formed over one substrate, and then the signal processing circuit **811** may be transferred to another substrate.

There are no particular limitations on the shape of the antenna **810**. For example, as illustrated in FIG. **3**A, an antenna **403** may be provided in the whole area around a signal processing circuit **402** over a substrate **401**. As illustrated in FIG. **3**B, a thin antenna **403** may be provided in the area around the signal processing circuit **402** over the substrate **401**. As illustrated in FIG. **3**C, the antenna may have such a shape that receives a high frequency electromagnetic wave. As illustrated in FIG. **3**D, the antenna may have a 180-degree nondirectional shape. As illustrated in FIG. **3**E, the antenna may have a stick-like elongated shape. For example, the shape such as a so-called dipole antenna, a loop antenna, a Yagi antenna, a patch antenna, or a minute antenna can be employed.

Although FIGS. **3**A to **3**E do not illustrate elements corresponding to the battery and the display element for simple description, the radio field intensity measurement device according to Embodiment Mode 1 includes a battery and a display element.

The antenna **810** illustrated in FIG. **7**A may be formed over the substrate provided with the signal processing circuit **811** or a substrate different from the substrate provided with the signal processing circuit **811**. Various types of substrates can be used as a substrate to be provided with the antenna **810**, and not-limiting examples of the substrate includes a single crystalline substrate, an SOI substrate, a glass substrate, a quartz substrate, a plastic substrate, a paper substrate, a cellophane substrate, a stone substrate and the like. In the case where the antenna **810** is formed over the same substrate as the signal processing circuit **811**, the antenna **810** may be formed by depositing a conductive film by sputtering, CVD, spin coating, or the like and then patterning the conductive film; or the antenna **810** may be formed by a droplet discharge method typified by an ink-jet method, a screen printing method, or the like. Also in the case where the antenna **810** is formed over a substrate which is different from the substrate over which the signal processing circuit **811** is formed, the antenna **810** can be formed by any of the aforementioned methods; however, preferably, the antenna **810** is formed by the screen printing method.

There are no particular limitations on the method of connecting the substrate provided with the signal processing circuit to the antenna. For example, wire bonding or a bump may be adopted to connect the antenna and the substrate provided with the signal processing circuit, or a method where a surface of the substrate provided with a signal processing circuit formed in a chip form is made as an electrode and the electrode is attached to the antenna may be employed. In this method, an anisotropic conductive film (ACF) can be used to connect the antenna and the substrate.

In addition, an appropriate length of the antenna varies depending on a frequency for receiving signals. For example, when the frequency is 2.45 GHz, a half-wave dipole antenna may have a length of a half wavelength (about 60 mm), or a monopole antenna may have a length of a quarter wavelength (about 30 mm).

The antenna may include a means of changing frequency of a received signal. For example, when a loop antenna is used for the antenna, a resonant circuit may be formed from an antenna coil **901** and a capacitor **902** included in the antenna **110** as illustrated in FIG. **8**.

Further, in FIG. **7**A, the antenna **810** is formed over the same substrate as the signal processing circuit **811**, or may be provided as an external antenna. As illustrated in FIG. **7**A, when the antenna **810** is formed over the same substrate **801** as the signal processing circuit **811**, the shape of the antenna is preferably a shape of a minute loop antenna, a minute dipole antenna or the like.

As the battery **812**, secondary batteries can be used, such as a lithium ion battery, a lithium secondary battery, a nickel hydride battery, a nickel cadmium battery, an organic radical battery, a lead-acid battery, an air secondary battery, a nickel zinc battery, a silver zinc battery, and the like. The battery is not limited to these examples, and a high-capacity capacitor may be used. In particular, a lithium ion battery and a lithium secondary battery have high charging and discharging capacity. Therefore, such a lithium ion battery or such a lithium secondary battery can be used as a battery provided for the radio field intensity measurement device of Embodiment Mode 1 in the present invention, and thus miniaturization thereof can be achieved. It is to be noted that an active material or an electrolyte of a lithium ion battery is formed by a sputtering method; therefore, the battery **812** may be formed over a substrate over which the signal processing circuit **811** is formed or a substrate over which the antenna **810** is formed. The battery **812** is formed over the substrate over which the signal processing circuit **811** or the antenna **810** is formed, and thus yield is improved. In a metal lithium battery, a transition metal oxide including lithium ions, a metal oxide, a metal sulfide, an iron compound, a conductive polymer, an organic sulfur compound, or the like is used for an anode active material; lithium (alloy) is used for a cathode active material; and an organic electrolyte solution, a polymer electrolyte, or the like is used for an electrolyte. Therefore, the battery **812** can have higher charging and discharging capacity.

For the display element **813**, an element including a material exhibiting chromism phenomena, such as a thermochromic material or an electrochromic material, can be used, but not limited to this element. In particular, as an element including a thermochromic material (also referred to as a thermochromic element), an element including a thermotropic liquid crystal (also referred to as a thermochromic liquid crystal), especially an element including a cholesteric liquid crystal is preferable, and the cholesteric liquid crystal may include cholesteryl oleyl carbonate, cholesteryl nonanoate, or cholesteryl benzoate. In addition, as the element including the electrochromic material (also referred to as an electrochromic element), an element including a metal oxide such as tungsten oxide or a related compound thereof may be used.

The structure of the radio field intensity measurement device according to Embodiment Mode 1 in the present invention is not limited to that of FIG. **7**A. For example, in FIG. **7**B, the signal processing circuit **811** is provided between the antenna **810** and the battery **812**; however, the battery **812** may be provided between the antenna **810** and the signal processing circuit **811** or the antenna **810** may be provided between the battery **812** and the signal processing circuit **811**. The area ratio of the antenna **810**, the battery **812** and the signal processing circuit **811** is not limited to the example of FIGS. **7**A and **7**B. In other words, in the case where each layer in the cross-section of the radio field intensity measurement device according to this embodiment mode in the present invention is seen, there are no particular limitations on the positional relationship of the antenna **810**, the battery **812** and the signal processing circuit **811**. In addition, the antenna **810** and the signal processing circuit **811** may be formed over different substrates, or the antenna **810**, the signal processing circuit **811**, and the battery **812** may be formed over the same substrate. Note that, preferably, the display element **813** is disposed in the uppermost layer for improving visibility and has a large area.

The radio field intensity measurement device of Embodiment Mode 1 in the present invention has a battery which can store power, and replacing batteries is not needed. Furthermore, even when a received signal is weak, power can be supplied from the battery to the signal processing circuit, and thus the radio field intensity measurement device can operate to measure the intensity of the radiowave. In other words, since the radio field intensity measurement device can measure the intensity of the radiowave having a weak signal, sensitivity improvement and stable measurement of the radio field intensity measurement device can be achieved.

Moreover, when a received signal is strong, the battery can be automatically charged, and thus it is unnecessary that a user bothers charging. Needless to say, if the power stored in the battery becomes small, a user can easily charge the battery by himself/herself.

Embodiment Mode 2

Embodiment Mode 2 will describe a mode in which a display element including a thermochromic material is formed.

FIGS. **13**A and **13**B schematically illustrate a display element in the present invention. A display element **2500** includes a resistance heating element **2502**, a thermochromic material **2503**, a transparent substrate **2504**, a connection terminal **2510** and a connection terminal **2511** over a light-shielding substrate **2501**. One of the connection terminals **2510** and **2511** is connected to a power supply terminal. For example, one of the connection terminals **2510** and **2511** is connected to the amplifier circuit **114** in Embodiment Mode 1. Note that the other of the connection terminals **2510** and **2511**, which is not connected to the power supply terminal, is connected to a GND terminal.

The structure of the display element in Embodiment Mode 2 is not limited to that in FIGS. **13**A and **13**B. For example, the thermochromic material **2503** is arranged above the resistance heating element **2502** in FIGS. **13**A and **13**B; alternatively the resistance heating element **2502** may be arranged over the thermochromic material **2503**. The shape and area of the resistance heating element **2502** and the thermochromic material **2503** are not limited to those of FIGS. **13**A and **13**B. For example, a comb-like shape or a convex-concave shape may be employed. Wider areas of the resistance heating element **2502** and the thermochromic material **2503** are preferably in contact with each other to enhance thermal conductivity.

In this embodiment mode, "the resistance heating element" indicates general elements which generate heat by electrical power. The amount of generated heat is changed in accordance with the power amount supplied from a connection terminal to the resistance heating element. Various substances can be used as materials of the resistance heating element in this embodiment mode. Thus, there are no particular limitations on the applicable material for the resistance hating element.

The thermochromic material in this embodiment mode indicates general substances which exhibit thermochromism phenomena. The thermochromism phenomenon is phenomena that color of a material is reversibly changed by heat stimulation. Thus, color is changed depending on the amount of heat supplied from the resistance heating element **2502**. In other words, color is changed in accordance with the amount of power supplied to the display element through the connection terminal. Various substances can be used as a themlochromic material included in the display element of this embodiment mode. Thus, there are no particular limitations on the type of the applicable thermochromic material.

A cholesteric liquid crystal, which is one example of thermochromic material in this embodiment mode, has a feature that a torsional state of the helix is changed depending on temperature. The molecular structure of the cholesteric liquid crystal and the principal of color change depending on the change of the molecular structure of the cholesteric liquid crystal are described with reference to FIGS. **14**A, **14**B and FIGS. **15**A, **15**B.

The cholesteric liquid crystal preferably includes cholesteryl oleyl carbonate in which one side of a carbonate group **2100** is bound to a cholesteryl group **2101** and the other side of the carbonate group is bound to an oleyl group **2102** which is a straight-chain hydrocarbon group as illustrated in FIG. **14**A. In FIG. **14**A, cholesteryl oleyl carbonate, a compound in which the carbonate group **2100** and the oleyl group **2102** are bound to the cholesteryl group **2101** is shown. Cholesteryl benzoate, a compound in which a benzoate group **2103** is bonded to the chlesteryl group **2101**, instead of the carbonate group **2100** and the oleyl group **2102**, as illustrated in FIG. **14**B, or cholesteryl nanoate, a compound in which a nanoate group **2104** is bonded to the chlesteryl group **2101**, instead of the carbonate group **2100** and the oleyl group **2102**, as illustrated in FIG. **14**C may be used. The mixed ratio of liquid crystal molecules including different straight-chain hydrocarbons such as cholesteryl oleyl carbonate, cholesteryl nanonate, and cholesteryl benzoate is changed to change the color of the cholesteric liquid crystal.

The cholesteric liquid crystal has a helical molecular structure and partially reflects incident light. This reflecting property is changed depending on the torsional state of the helix. For example, a cholesteric liquid crystal molecule having a pitch P selectively reflects only a wavelength (λ=n (refractive index of a cholesteric liquid crystal)$\times$P) of wavelengths included in incident light. For example, the liquid crystal molecule **2002** of FIG. **15**A has a torsion corresponding to ¼ pitch in a distance d between a transparent substrate **2000** and a light-shielding substrate **2001**, and thus only a wavelength ($\lambda=n\times P=n\times 4d$) of wavelengths included in the incident light **2003** is selectively reflected. In addition, a liquid crystal molecule **2002** illustrated in FIG. **15**B has a torsion corresponding to ¾ pitch in the distance d, and thus a wavelength ($\lambda=n\times P=n\times 4/3d$) of wavelengths included in the incident light **2003** is selectively reflected.

Human eyes recognize a difference in a wavelength of light as a difference of a color. Therefore, reflection light **2004** of FIG. **15**A and reflection light **2004** of FIG. **15**B have different wavelengths and are recognized as different colors.

The transparent substrate **2000** illustrated in FIGS. **15**A and **15**B may be transparent to human eyes. Preferably, the substrate transmits all wavelengths. The light-shielding substrate **2001** illustrated in FIGS. **15**A and **15**B may be a substrate which is black to human eyes. Preferably, the substrate absorbs all wavelengths.

FIG. **16** is a cross-sectional view illustrating a thermochromic element which is a display element including a thermochromic material. Wirings **2203***a* and **2203***b* are provided over the light-shielding substrate **2201** with a base layer **2202** interposed therebetween. The wiring **2203***a* and the wiring **2203***b* are connected to a resistance heating element **2229** in a contact portion **2206** and a contact portion **2207** provided in an interlayer insulating film **2204** and an insulating film **2205**. The resistance heating element **2229** generates heat by current flowing between the contact opening portion **2206** and the contact opening portion **2207** to heat a thermochromic material **2211**. Note that the wirings **2203***a* and **2203***b* are connected to connection terminals in FIG. **13**.

A transparent substrate **2214** is disposed opposite to the light-shielding substrate **2201**. A thermochromic material **2211** is provided between the light-shielding substrate **2201** and the transparent substrate **2214**. The distance between the light-shielding substrate **2201** and the transparent substrate **2214** is kept by a spacer **2210**. After a thermochromic material **2211** is provided between the light-shielding substrate **2201** and the transparent substrate **2214**, the light-shielding substrate **2201** and the transparent substrate **2214** are fixed by a sealing material **2220**. It is preferable that the distance between the light-shielding substrate **2201** and the transparent substrate **2214** is narrow, since a small amount of the thermochromic material **2211** is used and the heat amount of the thermochromic material **2211** to be heated is small, which achieves rapid color change.

In such a display element, by voltage application to the resistance heating element **2229**, the heat amount supplied to the thermochromic material **2211** is changed, and thus the state of the thermochromic material **2211** is changed, so that a color tone reflection light **2231** is different from that of incident light **2230**.

Embodiment 1

Embodiment 1 will describe an example of a method for manufacturing the radio field intensity measurement device shown in the above-described embodiment modes with reference to drawings. In this embodiment, a structure in which an antenna, and a signal processing circuit of the radio field intensity measurement device are formed using thin film transistors over the same substrate will be explained. It is to be noted that when an antenna and a signal processing circuit are formed together over the same substrate, reduction in size of the radio field intensity measurement device can be achieved, which is advantageous. In addition, in this embodiment, an example will be explained, in which a thin-film secondary battery is used as the battery in the signal processing circuit. Needless to say, instead of the secondary battery, a capacitor such as an electric double layer capacitor may be used.

First, a peeling layer **1303** is formed over one surface of a substrate **1301** with an insulating film **1302** interposed therebetween, and then an insulating film **1304** functioning as a base film and a semiconductor film (e.g., a film containing amorphous silicon) **1305** are stacked thereover (see FIG. **17**A). It is to be noted that the insulating film **1302**, the peeling layer **1303**, the insulating film **1304**, and the semiconductor film **1305** can be formed consecutively.

The substrate **1301** is selected from a glass substrate, a quartz substrate, a metal substrate (e.g., a ceramic substrate or a stainless steel substrate), a semiconductor substrate such as a Si substrate, or the like. Alternatively, a plastic substrate made of polyethylene terephthalate (PET), polyethylene naphthalate (PEN), polyether sulfone (PES), acrylic, or the like can be used. In this process, although the peeling layer **1303** is provided over the entire surface of the substrate **1301** with the insulating film **1302** interposed therebetween, the peeling layer **1303** can also be selectively formed by photolithography after being provided over the entire surface of the substrate **1301**.

The insulating films **1302** and **1304** are formed using insulating materials such as silicon oxide, silicon nitride, silicon oxynitride (SiO_xN_y, where x>y>0), or silicon nitride oxide (SiN_xO_y, where x>y>0) by a CVD method, a sputtering method, or the like. For example, when each of the insulating films **1302** and **1304** is formed to have a two-layer structure, a silicon nitride oxide film may be formed as a first insulating film and a silicon oxynitride film may be formed as a second insulating film. In addition, a silicon nitride film may be formed as a first insulating film and a silicon oxide film may be formed as a second insulating film. The insulating film **1302** functions as a blocking layer which prevents an impurity element contained in the substrate **1301** from getting mixed into the peeling layer **1303** or elements formed thereover. The insulating film **1304** functions as a blocking layer which prevents an impurity element contained in the substrate **1301** or the peeling layer **1303** from getting mixed into elements formed over the insulating film **1304**. In this manner, providing the insulating films **1302** and **1304** which function as the blocking layers can prevent adverse effects on the elements formed over the peeling layer **1303** or the insulating film **1304**, which would otherwise be caused by an alkali metal such as Na or an alkaline earth metal contained in the substrate **1301** or by the impurity element contained in the peeling layer **1303**. It is to be noted that when quartz is used for the substrate **1301**, for example, the insulating films **1302** and **1304** may be omitted.

The peeling layer **1303** may be formed using a metal film, a stacked structure of a metal film and a metal oxide film, or the like. As a metal film, either a single layer or stacked layers is/are formed using an element selected from tungsten (W), molybdenum (Mo), titanium (Ti), tantalum (Ta), niobium (Nb), nickel (Ni), cobalt (Co), zirconium (Zr), zinc (Zn), ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), and iridium (Ir), or an alloy material or a compound material containing such an element as its main component. In addition, such materials can be formed by a sputtering method, various CVD methods such as a plasma CVD method, or the like. A stacked structure of a metal film and a metal oxide film can be obtained by the steps of forming the above-described metal film, applying plasma treatment thereto under an oxygen atmosphere or an N_2O atmosphere or applying heat treatment thereto under an oxygen atmosphere or an N_2O atmosphere, and thereby forming oxide or oxynitride of the metal film on the surface of the metal film. For example, when a tungsten film is provided as a metal film by a sputtering method, a CVD method, or the like, a metal oxide film of tungsten oxide can be formed on the surface of the tungsten film by application of plasma treatment to the tungsten film. In that case, the tungsten oxide can be represented by WO_x where x is in the range of 2 to 3. For example, there are cases where x is 2 (WO_2), x is 2.5 (W_2O_5), x is 2.75 (W_4O_{11}), x is 3 (WO_3), and the like. When tungsten oxide is formed, there is no particular limitation on the value of x, and thus, which of the above oxides is to be formed may be determined base on the etching rate or the like. In addition, after a metal film (e.g., tungsten) is formed, an insulating film formed of silicon oxide (SiO_2) or the like may be formed over the metal film by a sputtering method, and also metal oxide (e.g., tungsten oxide on tungsten) may be formed on the metal film. Moreover, high-density-plasma treatment as described above may be applied as the plasma treatment, for example. Besides, metal nitride or metal oxynitride may also be formed. In that case, plasma treatment or heat treatment may be applied to the metal film under a nitrogen atmosphere or an atmosphere containing nitrogen and oxygen.

The amorphous semiconductor film **1305** is formed with a thickness of 25 to 200 nm (preferably, 30 to 150 nm) by a sputtering method, an LPCVD method, a plasma CVD method, or the like.

Next, the amorphous semiconductor film **1305** is crystallized by laser irradiation. Alternatively, the crystallization of the amorphous semiconductor film **1305** may be performed by a method combining the laser crystallization with a thermal crystallization method using RTA or an annealing furnace or with a thermal crystallization method using a metal element that promotes the crystallization. After that, the crystallized semiconductor film is etched into a desired shape, whereby crystalline semiconductor films **1305***a* to **1305***f* are formed. Then, a gate insulating film **1306** is formed so as to cover the semiconductor films **1305***a* to **1305***f* (see FIG. **17**B).

The gate insulating film **1306** is formed using an insulating material such as silicon oxide, silicon nitride, silicon oxynitride (SiO_xN_y, where x>y>0), or silicon nitride oxide (SiN_xO_y, where x>y>0) by a CVD method, a sputtering method, or the like. For example, when the gate insulating film **1306** is formed to have a two-layer structure, it is preferable to form a silicon oxynitride film as a first insulating film and form a silicon nitride oxide film as a second insulating film. Alternatively, it is also preferable to form a silicon oxide film as a first insulating film and form a silicon nitride film as a second insulating film.

An example of a formation process of the crystalline semiconductor films **1305***a* to **1305***f* is briefly explained below. First, an amorphous semiconductor film with a thickness of 50 to 60 nm is formed by a plasma CVD method. Then, a solution containing nickel which is a metal element that promotes crystallization is retained on the amorphous semiconductor film, which is followed by dehydrogenation treatment (500° C. for one hour) and thermal crystallization treatment (550° C. for four hours). Thus, a crystalline semiconductor film is formed. Then, the crystalline semiconductor film is subjected to laser irradiation and then a photolithography process to form the crystalline semiconductor films **1305***a* to **1305***f*. It is to be noted that crystallization of the amorphous semiconductor film may be performed only by laser irradiation, not by thermal crystallization which uses a metal element that promotes crystallization.

As a laser oscillator used for crystallization, either a continuous wave laser (a CW laser) or a pulsed laser can be used. As a laser that can be used here, there are gas lasers such as an Ar laser, a Kr laser, and an excimer laser; a laser whose medium issingle-crystalline YAG, YVO_4, forsterite (Mg_2SiO_4), $YAlO_3$, or $GdVO_4$ or polycrystalline (ceramic) YAG, Y_2O_3, YVO_4, $YAlO_3$, or $GdVO_4$ doped with one or more of Nd, Yb, Cr, Ti, Ho, Er, Tm, and Ta as a dopant; a glass laser; a ruby laser; an alexandrite laser; a Ti:sapphire laser; a copper vapor laser; and a gold vapor laser. When irradiation is performed with the fundamental wave of such a laser beam or the second to fourth harmonics of the fundamental wave, crystals with a large grain size can be obtained. For example, the second harmonic (532 nm) or the third harmonic (355 nm) of an Nd:YVO_4 laser (the fundamental wave of 1064 nm) can be used. In this case, a laser power density of approximately 0.01 to 100 MW/cm^2 (preferably, 0.1 to 10 MW/cm^2) is needed, and irradiation is performed with a scanning rate of approximately 10 to 2000 cm/sec. It is to be noted that the laser whose medium is single crystal YAG, YVO_4, forsterite (Mg_2SiO_4), $YAlO_3$, or $GdVO_4$ or polycrystalline (ceramic) YAG, Y_2O_3, YVO_4, $YAlO_3$, or $GdVO_4$ doped with one or more of Nd, Yb, Cr, Ti, Ho, Er, Tm, and Ta as a dopant; an Ar ion laser, or a Ti:sapphire laser can be used as a CW laser, whereas it can also be used as a pulsed laser with a repetition rate of 10 MHz or more by a Q-switch operation, mode locking, or the like. When a laser beam with a repetition rate of 10 MHz or more is used, a semiconductor film is irradiated with the next pulse during the period in which the semiconductor film has been melted by the laser beam and is solidified. Therefore, unlike the case of using a pulsed laser with a low repetition rate, a solid-liquid interface in the semiconductor film can be continuously moved. Thus, crystal grains which have grown continuously in the scanning direction can be obtained.

The gate insulating film **1306** may be formed by oxidization or nitridation of the surfaces of the semiconductor films **1305***a* to **1305***f* by the above-described high-density plasma treatment. For example, plasma treatment with a mixed gas of a rare gas such as He, Ar, Kr, or Xe, and oxygen, nitrogen oxide (NO_2), ammonia, nitrogen, or hydrogen is conducted. When plasma is excited by the introduction of microwaves, plasma with a low electron temperature and high density can be generated. With oxygen radicals (which may include OH radicals) or nitrogen radicals (which may include NH radicals) which are generated by the high-density plasma, the surfaces of the semiconductor films can be oxidized or nitrided.

By such high-density plasma treatment, an insulating film with a thickness of 1 to 20 nm, typically 5 to 10 nm, is formed on the semiconductor films. Since the reaction in this case is a solid-phase reaction, the interface state density between the insulating film and the semiconductor films can be quite low. Since such high-density plasma treatment directly oxidizes (or nitrides) the semiconductor films (crystalline silicon or polycrystalline silicon), desirably, the insulating film can be formed with extremely little unevenness. In addition, since crystal grain boundaries of crystalline silicon are not strongly oxidized, an excellent state is obtained. That is, by the solid-phase oxidation of the surfaces of the semiconductor films by high-density plasma treatment which is described in this embodiment, an insulating film with a uniform thickness and low interface state density can be formed without excessive oxidation reaction at the crystal grain boundaries.

As the gate insulating film, only an insulating film formed by high-density plasma treatment may be used, or a stacked layer may be employed, which is obtained by deposition of an insulating film such as silicon oxide, silicon oxynitride, or silicon nitride on the insulating film, by a CVD method using plasma or thermal reaction. In either case, a transistor which includes such an insulating film formed by high-density plasma treatment in a part or the whole of its gate insulating film can have reduced characteristic variations.

In addition, the semiconductor films **1305***a* to **1305***f*, which are obtained by irradiation of a semiconductor film with a continuous wave laser beam or a laser beam oscillated with a repetition rate of 10 MHz or more and scanning the semiconductor film with the laser beam in one direction to crystallize the semiconductor film, have a characteristic in that their crystals grow in the beam scanning direction. Transistors are each arranged so that its channel length direction (direction in which carriers move when a channel formation region is formed) is aligned with the scanning direction, and the above-described gate insulating film is combined with the semiconductor film, whereby thin film transistors (TFTs) with high electron field effect mobility and reduced variations in characteristics can be obtained.

Next, a first conductive film and a second conductive film are stacked over the gate insulating film **1306**. Here, the first conductive film is formed to a thickness of 20 to 100 nm by a CVD method, a sputtering method, or the like. The second conductive film is formed to a thickness of 100 to 400 nm. The first conductive film and the second conductive film are formed of an element selected from tantalum (Ta), tungsten (W), titanium (Ti), molybdenum (Mo), aluminum (Al), copper (Cu), chromium (Cr), niobium (Nb), or the like, or an alloy material or a compound material containing such an element as its main component. Alternatively, the first conductive film and the second conductive film are formed of semiconductor materials typified by polycrystalline silicon doped with an impurity element such as phosphorus. As a combination example of the first conductive film and the second conductive film, a tantalum nitride film and a tungsten film; a tungsten nitride film and a tungsten film; a molybdenum nitride film and a molybdenum film; and the like can be given. Tungsten and tantalum nitride have high heat resistance. Therefore, after forming the first conductive film and the second conductive film, thermal treatment for the purpose of heat activation can be applied thereto. In addition, in the case where a two-layer structure is not employed, but a three-layer structure is employed, it is preferable to use a stacked structure of a molybdenum film, an aluminum film, and a molybdenum film.

Next, a resist mask is formed by photolithography, and etching treatment is conducted to form gate electrodes and gate lines. Thus, gate electrodes **1307** are formed above the semiconductor films **1305***a* to **1305***f*. Here, a stacked structure of a first conductive film **1307***a* and a second conductive film **1307***b* is shown as an example of the gate electrode **1307**.

Next, the semiconductor films **1305***a* to **1305***f* are doped with an n-type impurity element at low concentration, using the gate electrodes **1307** as masks by an ion doping method or an ion implantation method. Then, a resist mask is selectively formed by photolithography, and the semiconductor films **1305***c* and **1305***e* are doped with a p-type impurity element at high concentration. As an n-type impurity element, phosphorus (P), arsenic (As), or the like can be used. As a p-type impurity element, boron (B), aluminum (Al), gallium (Ga), or the like can be used. Here, phosphorus (P) is used as an n-type impurity element and is selectively introduced into the semiconductor films **1305***a* to **1305***f* so as to be contained at concentrations of 1×10^{15} to $1\times10^{19}/cm^3$. Thus, n-type impurity regions **1308** are formed. In addition, boron (B) is used as a p-type impurity element, and is selectively introduced into the semiconductor films **1305***c* and **1305***e* so as to be contained at concentrations of 1×10^{19} to $1\times10^{20}/cm^3$. Thus, p-type impurity regions **1309** are formed (see FIG. **17**C).

Subsequently, an insulating film is formed so as to cover the gate insulating film **1306** and the gate electrodes **1307**. The insulating film is formed to have either a single layer or a stacked layer of a film containing an inorganic material such as silicon, silicon oxide, or silicon nitride, or a film containing an organic material such as an organic resin by a plasma CVD method, a sputtering method, or the like. Next, the insulating film is selectively etched by anisotropic etching mainly in the perpendicular direction, so that insulating films **1310** (also referred to as sidewalls) which are in contact with the side surfaces of the gate electrodes **1307** are formed. The insulating films **1310** are used as masks in doping for forming LDD (Lightly Doped Drain) regions.

Next, the semiconductor films **1305***a*, **1305***b*, **1305***d*, and **1305***f* are doped with an n-type impurity element at high concentration, using resist masks formed by photolithography, the gate electrodes **1307** and the insulating films **1310** as masks. Thus, n-type impurity regions **1311** are formed. Here, phosphorus (P) is used as an n-type impurity element, and is selectively introduced into the semiconductor films **1305***a*, **1305***b*, **1305***d*, and **1305***f* so as to be contained at concentrations of 1×10^{19} to $1\times10^{20}/cm^3$. Thus, the n-type impurity regions **1311** with higher concentration of impurity than that of the impurity regions **1308** are formed.

Through the above steps, n-channel thin film transistors **1300***a*, **1300***b*, **1300***d*, and **1300***f*, and p-channel thin film transistors **1300***c* and **1300***e* are formed (see FIG. **17**D).

In the n-channel thin film transistor **1300***a*, a channel formation region is formed in a region of the semiconductor film **1305***a* which overlaps with the gate electrode **1307**; the impurity regions **1311** serving as source and drain regions are formed in regions of the semiconductor film **1305***a* which do not overlap with the gate electrode **1307** and the insulating film **1310**; and low concentration impurity regions (LDD regions) are formed in regions of the semiconductor film **1305***a* which overlap with the insulating film **1310**,between the channel formation region and the impurity regions **1311**. Similarly, channel formation regions, low concentration impurity regions, and the impurity regions **1311** are formed in the n-channel thin film transistors **1300***b*, **1300***d*, and **1300***f*.

In the p-channel thin film transistor **1300***c*, a channel formation region is formed in a region of the semiconductor film **1305***c* which overlaps with the gate electrode **1307**, and the impurity regions **1309** serving as source and drain regions are formed in regions of the semiconductor film **1305***c* which do not overlap with the gate electrode **1307**. Similarly, a channel formation region and the impurity regions **1309** are formed in the p-channel thin film transistor **1300***e*. Here, although LDD regions are not formed in the p-channel thin film transistors **1300***c* and **1300***e*, LDD regions may be provided in the p-channel thin film transistors or a structure without LDD regions may be applied to the n-channel thin film transistors.

Next, an insulating film with a single layer structure or a stacked layer structure is formed so as to cover the semiconductor films **1305***a* to **1305***f*, the gate electrodes **1307**, and the like. Then, conductive films **1313** electrically connected to the impurity regions **1309** and **1311** which form the source and drain regions of the thin film transistors **1300***a* to **1300***f* are formed over the insulating film (see FIG. **18**A). The insulating film is formed with a single layer or a stacked layer, using an inorganic material such as silicon oxide or silicon nitride, an organic material such as polyimide, polyamide, benzocyclobutene, acrylic, or epoxy, a siloxane material, or the like by a CVD method, a sputtering method, an SOG method, a droplet discharging method, a screen printing method, or the like. In this embodiment, the insulating film is formed to have a two-layer structure, and a silicon nitride oxide film is formed as a first insulating film **1312***a* and a silicon oxynitride film is fainted as a second insulating film **1312***b*. In addition, the conductive films **1313** can form the source and drain electrodes of the thin film transistors **1300***a* to **1300***f*.

Before the insulating films **1312***a* and **1312***b* are formed or after one or both of the insulating films **1312***a* and **1312***b* is/are formed, heat treatment is preferably conducted for recovery of the crystallinity of the semiconductor films, activation of the impurity element which has been added into the semiconductor films, or hydrogenation of the semiconductor films. As the heat treatment, thermal annealing, laser annealing, RTA, or the like may be applied.

The conductive films **1313** are formed with a single layer or a stacked layer of an element selected from aluminum (Al), tungsten (W), titanium (Ti), tantalum (Ta), molybdenum (Mo), nickel (Ni), platinum (Pt), copper (Cu), gold (Au), silver (Ag), manganese (Mn), neodymium (Nd), carbon (C), and silicon (Si), or an alloy material or a compound material containing the element as its main component by a CVD method, a sputtering method or the like. An alloy material containing aluminum as its main component corresponds to, for example, a material which contains aluminum as its main component and also contains nickel, or a material which contains aluminum as its main component, and also contains nickel and one or both of carbon and silicon. The conductive films **1313** are preferably formed to have a stacked structure of a barrier film, an aluminum-silicon (Al—Si) film, and a barrier film or a stacked structure of a barrier film, an aluminum silicon (Al—Si) film, a titanium nitride film, and a barrier film. Note that the "barrier film" corresponds to a thin film formed of titanium, titanium nitride, molybdenum, or molybdenum nitride. Aluminum and aluminum silicon are suitable materials for forming the conductive films **1313** because they have low resistance value and are inexpensive. When barrier layers are provided as the top layer and the bottom layer, generation of hillocks of aluminum or aluminum silicon can be prevented. In addition, when a barrier film formed of titanium which is an element having a high reducing property is formed, even when there is a thin natural oxide film formed on the crystalline semiconductor film, the natural oxide film can be chemically reduced, and a favorable contact between the conductive film **1313** and the crystalline semiconductor film can be obtained.

Next, an insulating film **1314** is formed so as to cover the conductive films **1313**, and conductive films **1315***a* and **1315***b* electrically connected to the conductive films **1313** which form the source electrodes or the drain electrodes of the thin film transistors **1300***a* and **1300***f* are formed over the insulating film **1314**. In addition, a conductive film **1316** electrically connected to the conductive film **1313** which forms the source electrode or drain electrode of the thin film transistor **1300***b* is formed. It is to be noted that the conductive films **1315***a* and **1315***b* and the conductive film **1316** may be formed using the same material at the same time. The conductive films **1315***a* and **1315***b* and the conductive film **1316** can be formed using any of the above-described materials for the conductive film **1313**.

Next, a conductive film **1317** functioning as an antenna is formed so as to be electrically connected to the conductive film **1316** (see FIG. **18**B).

The insulating film **1314** can be formed with a single layer or a stacked layer of an insulating film containing oxygen and/or nitrogen such as silicon oxide (SiO_x), silicon nitride (SiN_x), silicon oxynitride (SiO_xN_y where x>y>0), or silicon nitride oxide (SiN_xO_y where x>y>0); a film containing carbon such as DLC (Diamond-Like Carbon); an organic material such as epoxy, polyimide, polyamide, polyvinyl phenol, benzocyclobutene, or acrylic; or a siloxane material such as a siloxane resin by a CVD method, a sputtering method or the like. It is to be noted that a siloxane material corresponds to a material having a bond of Si—O—Si. Siloxane has a skeleton structure with the bond of silicon (Si) and oxygen (O). As a substituent of siloxane, an organic group containing at least hydrogen (e.g., an alkyl group or aromatic hydrocarbon) is used. In addition, a fluoro group may be used as the substituent. Further, both a fluoro group and an organic group containing at least hydrogen may be used as the substituent.

The conductive film **1317** can be formed of a conductive material by a CVD method, a sputtering method, a printing method such as screen printing or gravure printing, a droplet discharging method, a dispenser method, a plating method, or the like. The conductive film **1317** is formed with a single layer or a stacked layer of an element selected from aluminum (Al), titanium (Ti), silver (Ag), copper (Cu), gold (Au), platinum (Pt), nickel (Ni), palladium (Pd), tantalum (Ta), or molybdenum (Mo), or an alloy material or a compound material containing such an element as its main component.

For example, when the conductive film **1317** functioning as an antenna is formed by a screen printing method, the conductive film can be provided by selective printing of a conductive paste in which conductive particles with a grain diameter of several nm to several tens of urn are dissolved or dispersed in an organic resin. The conductive particles can be at least one or more of metal particles selected from silver (Ag), gold (Au), copper (Cu), nickel (Ni), platinum (Pt), palladium (Pd), tantalum (Ta), molybdenum (Mo), titanium (Ti), and the like; fine particles of silver halide; and dispersive nanoparticles of such an element. In addition, the organic resin included in the conductive paste can be one or more of organic resins which function as a binder, a solvent, a dispersing agent, and a coating material of the metal particles. Typically, an organic resin such as an epoxy resin and a silicone resin can be given as examples. Preferably, a conductive paste is applied and baked to form the conductive film. For example, in the case of using fine particles (e.g., a grain diameter of 1 to 100 nm) containing silver as its main component as a material of the conductive paste, the conductive paste is baked and hardened at temperatures of 150 to 300° C., so that the conductive film can be obtained. Alternatively, it is also possible to use fine particles containing solder or lead-free solder as its main component. In that case, fine particles with a grain diameter of less than or equal to 20 μm are preferably used. Solder and lead-free solder have the advantage of low cost.

The conductive films **1315***a* and **1315***b* can function as wirings which are electrically connected to a secondary battery included in the radio field intensity measurement device of the present invention in a later step. In addition, in forming the conductive film **1317** which functions as an antenna, other conductive films may be separately formed so as to be electrically connected to the conductive films **1315***a* and **1315***b*, so that the conductive films can be utilized as the wirings to connect the conductive films **1315***a* and **1315***b* to the secondary battery.

Next, after forming an insulating film **1318** so as to cover the conductive film **1317**, a layer including the thin film transistors **1300***a* to **1300***f*, the conductive film **1317**, and the like (hereinafter referred to as an "element formation layer **1319**") is peeled off the substrate **1301**. Here, after forming opening portions in the element formation layer **1319** excluding the region of the thin film transistors **1300***a* to **1300***f* by laser irradiation (e.g., UV light) (see FIG. **18**C), the element formation layer **1319** can be peeled off the substrate **1301** with a physical force. The peeling layer **1303** may be selectively removed by introduction of an etchant into the opening portions before peeling the element formation layer **1319** off the substrate **1301**. As the etchant, a gas or a liquid containing halogen fluoride or an interhalogen compound is used. For example, when chlorine trifluoride (ClF_3) is used as the gas containing halogen fluoride, the element formation layer **1319** is peeled off the substrate **1301**. The whole peeling layer **1303** is not removed but part thereof may be left. Accordingly, the consumption of the etchant can be suppressed and process time for removing the peeling layer can be shortened. In addition, even after removing the peeling layer **1303**, the element formation layer **1319** can be held above the substrate **1301**. In addition, by reuse of the substrate **1301** from which the element formation layer **1319** has been peeled, cost reduction can be achieved.

The insulating film **1318** can be formed with a single layer or a stacked layer of an insulating film containing oxygen and/or nitrogen such as silicon oxide (SiO_x), silicon nitride (SiN_x), silicon oxynitride (SiO_xN_y where x>y>0), or silicon nitride oxide (SiN_xO_y where x>y>0); a film containing carbon such as DLC (Diamond-Like Carbon); an organic material such as epoxy, polyimide, polyamide, polyvinyl phenol, benzocyclobutene, or acrylic; or a siloxane material such as a siloxane resin by a CVD method, a sputtering method, or the like.

In this embodiment, after forming the opening portions in the element formation layer **1319** by laser irradiation, a first sheet material **1320** is attached to one surface of the element formation layer **1319** (the surface where the insulating film **1318** is exposed), and then the element formation layer **1319** is peeled off the substrate **1301** (see FIG. **19**A).

Next, a second sheet material **1321** is attached to the other surface of the element formation layer **1319** (the surface exposed by peeling), followed by one or both of heat treatment and pressurization treatment for attachment of the second sheet material **1321** (see FIG. **19**B). As the first sheet material **1320** and the second sheet material **1321**, a hot-melt film or the like can be used.

As the first sheet material **1320** and the second sheet material **1321**, a film on which antistatic treatment for preventing static electricity or the like has been applied (hereinafter referred to as an antistatic film) can be used. As examples of the antistatic film, a film in which an antistatic material is dispersed in a resin, a film to which an antistatic material is attached, and the like can be given. The film provided with an antistatic material can be a film with an antistatic material provided on one of its surfaces, or a film with an antistatic material provided on each of its surfaces. The film with an antistatic material provided on one of its surfaces may be attached to the layer so that the antistatic material is placed on the inner side of the film or the outer side of the film. The antistatic material may be provided for the entire surface of the film, or over a part of the film. As an antistatic material, a metal, indium tin oxide (ITO), or a surfactant such as an amphoteric surfactant, a cationic surfactant, or a nonionic surfactant can be used. Further, as an antistatic material, a resin material which contains a cross-linked copolymer having a carboxyl group and a quaternary ammonium base on its side chain, or the like can be used. Such a material is attached, mixed, or applied to a film, so that an antistatic film can be formed. The element formation layer is sealed using the antistatic film, so that the semiconductor elements can be protected from adverse effects such as external static electricity when dealt with as a commercial product.

It is to be noted that a thin-film secondary battery is connected to the conductive films **1315***a* and **1315***b*, so that the battery is formed. The connection with the secondary battery may be conducted before the element formation layer **1319** is peeled off the substrate **1301** (at the stage shown in FIG. **18**B or FIG. **18**C), after the element formation layer **1319** is peeled off the substrate **1301** (at the stage shown in FIG. **19**A), or after the element formation layer **1319** is sealed with the first sheet material and the second sheet material (at the stage shown in FIG. **19**B). An example where the element formation layer **1319** and the secondary battery are formed to be connected is explained below with reference to FIGS. **20**A and **20**B and FIGS. **21**A and **21**B.

In FIG. **18**B, conductive films **1331***a* and **1331***b* which are electrically connected to the conductive films **1315***a* and **1315***b*, respectively are formed at the same time as the conductive film **1317** which functions as an antenna. Then, the insulating film **1318** is formed so as to cover the conductive films **1317**, **1331***a*, and **1331***b*, followed by formation of opening portions **1332***a* and **1332***b* so that the surfaces of the conductive films **1331***a* and **1331***b* are exposed. After that, the opening portions are formed in the element formation layer **1319** by laser irradiation, and then the first sheet material **1332** is attached to one surface of the element formation layer **1319** (the surface where the insulating film **1318** is exposed), so that the element formation layer **1319** is peeled off the substrate **1301** (see FIG. **20**A).

Next, the second sheet material **1333** is attached to the other surface of the element formation layer **1319** (the surface exposed by peeling), and the element formation layer **1319** is peeled off the first sheet material **1332**. Therefore, a material with low viscosity is used as the first sheet material **1332**. Then, conductive films **1334***a* and **1334***b* which are electrically connected to the conductive films **1331***a* and **1331***b* respectively through the opening portions **1332***a* and **1332***b* are selectively formed (see FIG. **20**B).

The conductive films **1334***a* and **1334***b* are formed of a conductive material by a CVD method, a sputtering method, a printing method such as screen printing or gravure printing, a droplet discharging method, a dispenser method, a plating method, or the like. The conductive films **1334***a* and **1334***b* are formed with a single layer or a stacked layer of an element selected from aluminum (Al), titanium (Ti), silver (Ag), copper (Cu), gold (Au), platinum (Pt), nickel (Ni), palladium (Pd), tantalum (Ta), or molybdenum (Mo), or an alloy material or a compound material containing the element as its main component.

Although the example shown in this embodiment is the case where the conductive films **1334***a* and **1334***b* are formed after peeling the element formation layer **1319** off the substrate **1301**, the element formation layer **1319** may be peeled off the substrate **1301** after the formation of the conductive films **1334***a* and **1334***b*.

Next, in the case where a plurality of elements is formed over the substrate, the element formation layer **1319** is cut into elements (see FIG. **21**A). A laser irradiation apparatus, a dicing apparatus, a scribing apparatus, or the like can be used for the cutting. At this time, the plurality of elements formed over one substrate is separated from one another by laser irradiation.

Next, the separated elements are electrically connected to the secondary battery (see FIG. **21**B). In this embodiment, a thin-film secondary battery is used as the battery, in which a current-collecting thin film, a negative electrode active material layer, a solid electrolyte layer, a positive electrode active material layer, and a current-collecting thin film are sequentially stacked.

Conductive films **1336***a* and **1336***b* are formed of a conductive material by a CVD method, a sputtering method, a printing method such as screen printing or gravure printing, a droplet discharging method, a dispenser method, a plating method, or the like. The conductive films **1336***a* and **1336***b* are formed with a single layer or a stacked layer of an element selected from aluminum (Al), titanium (Ti), silver (Ag), copper (Cu), gold (Au), platinum (Pt), nickel (Ni), palladium (Pd), tantalum (Ta), and molybdenum (Mo), or an alloy material or a compound material containing such an element as its main component. The conductive material should have high adhesion to a negative electrode active material layer and also low resistance. In particular, aluminum, copper, nickel, vanadium, or the like is preferably used.

The structure of the thin-film secondary battery is described next. A negative electrode active material layer **1381** is formed over the conductive film **1336***a*. In general, vanadium oxide (V_2O_5) or the like is used. Next, a solid electrolyte layer **1382** is formed over the negative electrode active material layer **1381**. In general, lithium phosphate (Li_3PO_4) or the like is used. Next, a positive electrode active material layer **1383** is formed over the solid electrolyte layer **1382**. In general, lithium manganate ($LiMn_2O_4$) or the like is used. Lithium cobaltate ($LiCoO_2$) or lithium nickel oxide ($LiNiO_2$) may also be used. Next, a current-collecting thin film **1384** to serve as an electrode is formed over the positive electrode active material layer **1383**. The current-collecting thin film **1384** should have high adhesion to the positive electrode active material layer **1383** and also low resistance. For example, aluminum, copper, nickel, vanadium, or the like can be used.

Each of the above thin layers of the negative electrode active material layer **1381**, the solid electrolyte layer **1382**, the positive electrode active material layer **1383**, and the current-collecting thin film **1384** may be formed by a sputtering technique or an evaporation technique. In addition, the thickness of each layer is preferably 0.1 to 3 μm.

Next, an interlayer film **1385** is formed by application of a resin. The interlayer film **1385** is etched to form a contact hole. The interlayer film **1385** is not limited to a resin, and other films such as a CVD oxide film may be used as well; however, a resin is preferably used in terms of flatness. In addition, the contact hole may be formed without using etching, but using a photosensitive resin. Next, a wiring layer **1386** is formed over the interlayer film **1385** and connected to the conductive film **1336*b***. Thus, an electrical connection with the thin-film secondary battery is secured.

Here, the conductive films **1334*a*** and **1334*b*** which are provided in the element formation layer **1319** are connected to the conductive films **1336*a*** and **1336*b*** respectively, which serve as the connection terminals of the thin film secondary battery **1389**, which has been made in advance. Here, an example is shown in which an electrical connection between the conductive films **1334*a*** and **1336*a*** or an electrical connection between the conductive films **1334*b*** and **1336*b*** is performed by pressure bonding with an adhesive material such as an anisotropic conductive film (ACF) or an anisotropic conductive paste (ACP) interposed therebetween. In this embodiment, the example is shown, in which the connection is performed using conductive particles **1338** included in an adhesive resin **1337**. Alternatively, a conductive adhesive such as a silver paste, a copper paste, or a carbon paste; solder joint; or the like can be used.

The structures of such transistors can be various without being limited to the specific structure shown in this embodiment. For example, a multi-gate structure having two or more gate electrodes may be employed. When a multi-gate structure is employed, a structure in which channel regions are connected in series is provided; therefore, a structure in which a plurality of transistors are connected in series is provided. When a multi-gate structure is employed, various advantages can be obtained in that off-current can be reduced; withstand voltage of the transistor can be increased, so that the reliability is increased; and even if drain-source voltage changes when the transistor operates in the saturation region, a drain-source current does not change very much, and thus flat characteristics can be obtained. In addition, a structure in which gate electrodes are formed above and below a channel may also be employed. When a structure in which gate electrodes are formed above and below a channel is employed, the channel region is enlarged and the amount of current flowing therethrough can be increased. Thus, a depletion layer can be easily formed and the subthreshold swing (S value) can be decreased. When gate electrodes are formed above and below a channel, a structure in which a plurality of transistors is connected in parallel is provided.

In addition, any of the following structures may be employed: a structure in which a gate electrode is formed above a channel; a structure in which a gate electrode is formed below a channel; a staggered structure; and an inversely staggered structure.

Further, a structure in which a channel region is divided into a plurality of regions and the divided regions are connected in parallel or in series may be employed. In addition, a channel (or part thereof) may overlap with a source electrode or a drain electrode. However, when a structure in which a channel (or part thereof) overlaps with a source electrode or a drain electrode is employed, electric charges can be prevented from being accumulated in part of the channel and thus an unstable operation can be prevented. In addition, an LDD (Lightly Doped Drain) region may be provided. When an LDD region is provided, off-current can be reduced; the withstand voltage of the transistor can be increased, so that the reliability is increased; and even if drain-source voltage changes when the transistor operates in the saturation region, drain-source current does not change very much, and thus flat characteristics can be obtained.

The method of manufacturing the radio field intensity measurement device in this embodiment can be applied to any of the radio field intensity measurement devices in the other embodiments.

Embodiment 2

Embodiment 2 will describe an example of a method for manufacturing the radio field intensity measurement device described in the above embodiment modes, with reference to drawings. In this embodiment, a structure in which an antenna and a signal processing circuit of the radio field intensity measurement device are formed over the same substrate will be explained. It is to be noted that an antenna and a signal processing circuit are formed using transistors including channel formation regions formed on a single crystal substrate, together over the same single crystal substrate. When transistors formed using a single crystal substrate are used as the transistors, a radio field intensity measurement device having transistors with few characteristic variations can be formed, which is preferable. In addition, in this embodiment, an example is explained in which the thin-film secondary battery described in Embodiment 1 is used as the battery included in the signal processing circuit.

First, separated regions **2304** and **2306** (hereinafter simply referred to as regions **2304** and **2306**) are formed in a semiconductor substrate **2300** (see FIG. **22**A). The regions **2304** and **2306** provided in the semiconductor substrate **2300** are separated from each other by an insulating film (also referred to as a field oxide film) **2302**. The example shown here is the case where a single crystal Si substrate having n-type conductivity is used as the semiconductor substrate **2300**, and a p well **2307** is formed in the region **2306** of the semiconductor substrate **2300**.

Any substrate can be used as the substrate **2300** as long as it is a semiconductor substrate. For example, a single crystal Si substrate having n-type or p-type conductivity, a compound semiconductor substrate (e.g., a GaAs substrate, an InP substrate, a GaN substrate, a SiC substrate, a sapphire substrate, or a ZnSe substrate), an SOI (Silicon on Insulator) substrate formed by a bonding method or a SIMOX (Separation by IMplanted OXygen) method, or the like can be used.

The regions **2304** and **2306** can be formed by a LOCOS (LOCal Oxidation of Silicon) method, a trench isolation method, or the like.

In addition, the p well **2307** formed in the region **2306** of the semiconductor substrate **2300** can be formed by selective doping of the semiconductor substrate **2300** with a p-type impurity element. As a p-type impurity element, boron (B), aluminum (Al), gallium (Ga), or the like can be used.

In this embodiment, although the region **2304** is not doped with an impurity element because an n-type semiconductor substrate is used as the semiconductor substrate **2300**, an n well may be formed in the region **2304** by introduction of an n-type impurity element. As an n-type impurity element, phosphorus (P), arsenic (As), or the like can be used. When a p-type semiconductor substrate is used, on the other hand, the region **2304** may be doped with an n-type impurity element to form an n well, whereas the region **2306** may not be doped with an impurity element.

Next, insulating films **2332** and **2334** are formed so as to cover the regions **2304** and **2306**, respectively (see FIG. **22**B).

For example, surfaces of the regions **2304** and **2306** provided in the semiconductor substrate **2300** are oxidized by heat treatment, so that the insulating films **2332** and **2334** can be formed of silicon oxide films. Alternatively, the insulating films **2332** and **2334** may be formed to have a stacked structure of a silicon oxide film and a film containing oxygen and nitrogen (a silicon oxynitride film) by the steps of forming a silicon oxide film by a thermal oxidation method and then nitriding the surface of the silicon oxide film by nitridation treatment.

Further alternatively, the insulating films **2332** and **2334** can be formed by plasma treatment as described above. For example, the insulating films **2332** and **2334** can be formed using a silicon oxide (SiO_x) film or a silicon nitride (SiN_x) film which is obtained by application of high-density plasma oxidation or high-density plasma nitridation treatment to the surfaces of the regions **2304** and **2306** provided in the semiconductor substrate **2300**. Furthermore, after applying high-density plasma oxidation treatment to the surfaces of the regions **2304** and **2306**, high-density plasma nitridation treatment may be performed. In that case, silicon oxide films are formed on the surfaces of the regions **2304** and **2306**, and then silicon oxynitride films are formed on the silicon oxide films Thus, the insulating films **2332** and **2334** are each formed to have a stacked structure of the silicon oxide film and the silicon oxynitride film. In addition, high-density plasma oxidation or high-density nitridation treatment may be applied to the silicon oxide films after silicon oxide films are formed on the surfaces of the regions **2304** and **2306** by a thermal oxidation method.

The insulating films **2332** and **2334** formed over the regions **2304** and **2306** of the semiconductor substrate **2300** respectively function as the gate insulating films of transistors which are completed later.

Next, a conductive film is formed so as to cover the insulating films **2332** and **2334** which are formed over the regions **2304** and **2306**, respectively (see FIG. **22**C). Here, an example is shown in which conductive films **2336** and **2338** are sequentially stacked as the conductive film. Needless to say, the conductive film may be formed to have a single layer or a stacked structure of three or more layers.

As materials of the conductive films **2336** and **2338**, an element selected from tantalum (Ta), tungsten (W), titanium (Ti), molybdenum (Mo), aluminum (Al), copper (Cu), chromium (Cr), niobium (Nb), or the like, or an alloy material or a compound material containing such an element as its main component can be used. Alternatively, a metal nitride film obtained by nitridation of the above element can be used. Besides, a semiconductor material typified by polycrystalline silicon doped with an impurity element such as phosphorus can be used.

In this case, a stacked structure is employed in which the conductive film **2336** is formed using tantalum nitride and the conductive film **2338** is formed thereover using tungsten. Alternatively, it is also possible to form the conductive film **2336** using a single-layer film or a stacked film of tungsten nitride, molybdenum nitride, and/or titanium nitride and form the conductive film **2338** using a single-layer film or a stacked film of tantalum, molybdenum, and/or titanium.

Next, the stacked conductive films **2336** and **2338** are selectively removed by etching, so that the conductive films **2336** and **2338** remain above part of the regions **2304** and **2306**, respectively. Thus, gate electrodes **2340** and **2342** are formed (see FIG. **23**A).

Next, a resist mask **2348** is selectively formed so as to cover the region **2304**, and the region **2306** is doped with an impurity element, using the resist mask **2348** and the gate electrode **2342** as masks, so that impurity regions are formed (see FIG. **23**B). As an impurity element, an n-type impurity element or a p-type impurity element is used. As an n-type impurity element, phosphorus (P), arsenic (As), or the like can be used. As a p-type impurity element, boron (B), aluminum (Al), gallium (Ga), or the like can be used. Here, phosphorus (P) is used as the impurity element.

In FIG. **23**B, by introduction of an impurity element, impurity regions **2352** which form source and drain regions and a channel formation region **2350** are formed in the region **2306**.

Next, a resist mask **2366** is selectively formed so as to cover the region **2306**, and the region **2304** is doped with an impurity element, using the resist mask **2366** and the gate electrode **2340** as masks, so that impurity regions are formed (see FIG. **23**C). As the impurity element, an n-type impurity element or a p-type impurity element is used. As an n-type impurity element, phosphorus (P), arsenic (As), or the like can be used. As a p-type impurity element, boron (B), aluminum (Al), gallium (Ga), or the like can be used. At this time, an impurity element (e.g., boron (B)) of a conductivity type different from that of the impurity element introduced into the region **2306** in FIG. **23**B is used. As a result, impurity regions **2370** which form source and drain regions and a channel formation region **2368** are formed in the region **2304**.

Next, a second insulating film **2372** is formed so as to cover the insulating films **2332** and **2334** and the gate electrodes **2340** and **2342**. Then, wirings **2374**, which are electrically connected to the impurity regions **2352** and **2370** formed in the regions **2306** and **2304** respectively, are formed over the second insulating film **2372** (see FIG. **24**A).

The second insulating film **2372** can be formed with a single layer or a stacked layer of an insulating film containing oxygen and/or nitrogen such as silicon oxide (SiO_x), silicon nitride (SiN_x), silicon oxynitride (SiO_xN_y, where $x>y>0$), or silicon nitride oxide (SiN_xO_y, where $x>y>0$); a film containing carbon such as DLC (Diamond-Like Carbon); an organic material such as epoxy, polyimide, polyamide, polyvinyl phenol, benzocyclobutene, or acrylic; or a siloxane material such as a siloxane resin by a CVD method, a sputtering method or the like. A siloxane material corresponds to a material having a bond of Si—O—Si. Siloxane has a skeleton structure with the bond of silicon (Si) and oxygen (O). As a substituent of siloxane, an organic group containing at least hydrogen (e.g., an alkyl group or aromatic hydrocarbon) is used. Also, a fluoro group may be used as the substituent, or both a fluoro group and an organic group containing at least hydrogen may be used.

The wirings **2374** are formed with a single layer or a stacked layer of an element selected from aluminum (Al), tungsten (W), titanium (Ti), tantalum (Ta), molybdenum (Mo), nickel (Ni), platinum (Pt), copper (Cu), gold (Au), silver (Ag), manganese (Mn), neodymium (Nd), carbon (C), or silicon (Si), or an alloy material or a compound material containing such an element as its main component by a CVD method, a sputtering method or the like. An alloy material containing aluminum as its main component corresponds to, for example, a material which contains aluminum as its main component and also contains nickel, or a material which contains aluminum as its main component and also contains nickel and one or both of carbon and silicon. The wirings **2374** are preferably formed to have a stacked structure of a barrier film, an aluminum-silicon (Al—Si) film, and a barrier film or a stacked structure of a barrier film, an aluminum silicon (Al—Si) film, a titanium nitride film, and a barrier film. It is to be noted that the "barrier film" corresponds to a thin film formed of titanium, titanium nitride, molybdenum, or molybdenum nitride. Aluminum and aluminum silicon are suitable materials for forming the wirings **2374** because they have high resistance values and are inexpensive. When barrier layers are provided as the top layer and the bottom layer, generation of hillocks of aluminum or aluminum silicon can be prevented. When a barrier film formed of titanium which is an element having a high reducing property is formed, even when there is a thin natural oxide film formed on the crystalline semiconductor film, the natural oxide film can be chemically reduced, and a favorable contact between the wirings **2374** and the crystalline semiconductor film can be obtained.

It is to be noted that the structure of transistors of the present invention is not limited to the one shown in the drawing. For example, a transistor with an inversely staggered structure, a FinFET structure, or the like can be used. A FinFET structure is preferable because it can suppress a short channel effect which occurs along with reduction in transistor size.

The radio field intensity measurement device of the present invention includes a battery by which power can be stored in the signal processing circuit. As the battery, a capacitor such as an electric double layer capacitor or a thin-film secondary battery is preferably used. In this embodiment, a connection between the transistor formed in this embodiment and a thin-film secondary battery is explained.

In this embodiment, the secondary battery is stacked over the wiring **2374** connected to the transistor. The secondary battery has a structure in which a current-collecting thin film, a negative electrode active material layer, a solid electrolyte layer, a positive electrode active material layer, and a current-collecting thin film are sequentially stacked (see FIG. **24**B). Therefore, the material of the wiring **2374** which also has a function of the current-collecting thin film of the secondary battery should have high adhesion to the negative electrode active material layer and also low resistance. In particular, aluminum, copper, nickel, vanadium, or the like is preferably used.

Subsequently, the structure of the thin-film secondary battery is described. A negative electrode active material layer **2391** is formed over the wiring **2374**. In general, vanadium oxide (V_2O_5) or the like is used. Next, a solid electrolyte layer **2392** is formed over the negative electrode active material layer **2391**. In general, lithium phosphate (Li_3PO_4) or the like is used. Next, a positive electrode active material layer **2393** is formed over the solid electrolyte layer **2392**. In general, lithium manganate ($LiMn_2O_4$) or the like is used. Lithium cobaltate ($LiCoO_2$) or lithium nickel oxide ($LiNiO_2$) may also be used. Next, a current-collecting thin film **2394** to serve as an electrode is formed over the positive electrode active material layer **2393**. The current-collecting thin film **2394** should have high adhesion to the positive electrode active material layer **2393** and also low resistance. For example, aluminum, copper, nickel, vanadium, or the like can be used.

Each of the above-described thin layers of the negative electrode active material layer **2391**, the solid electrolyte layer **2392**, the positive electrode active material layer **2393**, and the current-collecting thin film **2394** may be formed by a sputtering technique or an evaporation technique. In addition, the thickness of each layer is preferably 0.1 to 3 μm.

Next, an interlayer film **2396** is formed by application of a resin. The interlayer film **2396** is etched to form a contact hole. The interlayer film is not limited to a resin, and other films such as a CVD oxide film may also be used; however, a resin is preferably used in terms of flatness. In addition, the contact hole may be formed without etching, but using a photosensitive resin. Next, a wiring layer **2395** is formed over the interlayer film **2396** and connected to a wiring **2397**. Thus, an electrical connection between the secondary battery and the transistor is secured.

With the above-described structure, the radio field intensity measurement device of the present invention can have a structure in which transistors are formed on a single crystal substrate and a thin-film secondary battery is formed thereover. Thus, the radio field intensity measurement device of the present invention can achieve flexibility as well as thinning and reduction in size.

The method of manufacturing the radio field intensity measurement device in this embodiment can be applied to any of the radio field intensity measurement devices in the other embodiments.

Embodiment 3

An example of a method for manufacturing a radio field intensity measurement device, which is different from that described in Embodiment 2, will be explained with reference to drawings.

First, an insulating film is formed over a substrate **2600**. Here, a single crystal Si substrate having n-type conductivity is used as the substrate **2600**, and insulating films **2602** and **2604** are formed over the substrate **2600** (see FIG. **25**A). For example, silicon oxide (SiO_x) is formed as the insulating film **2602** by application of heat treatment to the substrate **2600**, and then silicon nitride (SiN_x) is formed over the insulating film **2602** by a CVD method.

Any substrate can be used as the substrate **2600** as long as it is a semiconductor substrate, without particular limitations. For example, a single crystal Si substrate having n-type or p-type conductivity, a compound semiconductor substrate (e.g., a GaAs substrate, an InP substrate, a GaN substrate, a SiC substrate, a sapphire substrate, or a ZnSe substrate), an SOI (Silicon on Insulator) substrate fanned by a bonding method or a SIMOX (Separation by IMplanted OXygen) method, or the like can be used.

Alternatively, after forming the insulating film **2602**, the insulating film **2604** may be formed by nitridation of the insulating film **2602** by high-density plasma treatment. It is to be noted that the insulating film provided over the substrate **2600** may have a single-layer structure or a stacked structure of three or more layers.

Next, patterns of a resist mask **2606** are selectively formed over the insulating film **2604**, and selective etching is performed using the resist mask **2606** as a mask, so that recessed portions **2608** are selectively formed in the substrate **2600** (see FIG. **25**B). For the etching of the substrate **2600** and the insulating films **2602** and **2604**, plasma dry etching can be conducted.

Next, the patterns of the resist mask **2606** are removed, and then an insulating film **2610** is formed so as to fill the recessed portions **2608** formed in the substrate **2600** (see FIG. **25**C).

The insulating film **2610** is formed of an insulating material such as silicon oxide, silicon nitride, silicon oxynitride (SiO_xN_y, where x>y>0), or silicon nitride oxide (SiN_xO_y, where x>y>0) by a CVD method, a sputtering method, or the like. As the insulating film **2610**, a silicon oxide film is formed by an atmospheric pressure CVD method or a low-pressure CVD method using a TEOS (tetraethyl orthosilicate) gas.

Next, the surface of the substrate **2600** is exposed by grinding treatment or polishing treatment such as CMP (Chemical Mechanical Polishing). Here, by exposure of the surface of the substrate **2600**, regions **2612** and **2613** are formed between insulating films **2611** which are formed in the recessed portions **2608** of the substrate **2600**. The insulating film **2610** formed over the surface of the substrate **2600** is removed by grinding treatment or polishing treatment such as CMP, so that the insulating films **2611** are obtained. Subsequently, by selective introduction of a p-type impurity element, a p well **2615** is formed in the region **2613** of the substrate **2600** (see FIG. **26**A).

As a p-type impurity element, boron (B), aluminum (Al), gallium (Ga), or the like can be used. In this case, boron (B) is introduced into the region **2613** as the impurity element.

Further, in this embodiment, although the region **2612** is not doped with an impurity element because an n-type semiconductor substrate is used as the substrate **2600**, an n well may be formed in the region **2612** by introduction of an n-type impurity element. As an n-type impurity element, phosphorus (P), arsenic (As), or the like can be used.

When a p-type semiconductor substrate is used, on the other hand, the region **2612** may be doped with an n-type impurity element to form an n well, whereas the region **2613** may not be doped with an impurity element.

Next, insulating films **2632** and **2634** are formed over the surfaces of the regions **2612** and **2613** in the substrate **2600**, respectively (see FIG. **26**B).

For example, surfaces of the regions **2612** and **2613** provided in the substrate **2600** are oxidized by heat treatment, so that the insulating films **2632** and **2634** of silicon oxide films can be formed. Alternatively, the insulating films **2632** and **2634** may each be formed to have a stacked structure of a silicon oxide film and a film containing oxygen and nitrogen (a silicon oxynitride film) by the steps of forming a silicon oxide film by a thermal oxidation method and then nitriding the surface of the silicon oxide film by nitridation treatment.

Further alternatively, the insulating films **2632** and **2634** may be formed by plasma treatment as described above. For example, the insulating films **2632** and **2634** can be formed with a silicon oxide (SiO_x) film or a silicon nitride (SiN_x) film which is obtained by application of high-density plasma oxidation or high-density nitridation treatment to the surfaces of the regions **2612** and **2613** provided in the substrate **2600**. In addition, after application of high-density plasma oxidation treatment to the surfaces of the regions **2612** and **2613**, high-density plasma nitridation treatment may be conducted. In that case, silicon oxide films are formed on the surfaces of the regions **2612** and **2613** and then silicon oxynitride films are formed on the silicon oxide films. Thus, the insulating films **2632** and **2634** are each formed to have a stacked structure of the silicon oxide film and the silicon oxynitride film. In addition, silicon oxide films are formed on the surfaces of the regions **2612** and **2613** by a thermal oxidation method, and then high-density plasma oxidation treatment or high-density plasma nitridation treatment may be performed to the silicon oxide films.

It is to be noted that the insulating films **2632** and **2634** formed over the regions **2612** and **2613** of the substrate **2600** respectively function as the gate insulating films of transistors which are completed later.

Next, a conductive film is formed so as to cover the insulating films **2632** and **2634** which are formed over the regions **2612** and **2613** provided in the substrate **2600**, respectively (see FIG. **26**C). In this embodiment, an example is shown where conductive films **2636** and **2638** are sequentially stacked as the conductive film. Needless to say, the conductive film may be formed to have a single layer or a stacked structure of three or more layers.

As a material of the conductive films **2636** and **2638**, an element selected from tantalum (Ta), tungsten (W), titanium (Ti), molybdenum (Mo), aluminum (Al), copper (Cu), chromium (Cr), niobium (Nb), or the like, or an alloy material or a compound material containing such an element as its main component can be used. Alternatively, a metal nitride film obtained by nitridation of such an element can also be used. Furthermore, a semiconductor material typified by polycrystalline silicon doped with an impurity element such as phosphorus can also be used.

In this case, a stacked structure is employed in which the conductive film **2636** is formed using tantalum nitride and the conductive film **2638** is formed thereover using tungsten. Alternatively, it is also possible to form the conductive film **2636** using a single-layer film or a stacked film of tantalum nitride, tungsten nitride, molybdenum nitride, and/or titanium nitride and form the conductive film **2638** using a single-layer film or a stacked film of tungsten, tantalum, molybdenum, and/or titanium.

Next, the stacked conductive films **2636** and **2638** are selectively removed by etching, so that the conductive films **2636** and **2638** remain above part of the regions **2612** and **2613** of the substrate **2600**. Thus, conductive films **2640** and **2642** functioning as gate electrodes are formed (see FIG. **27**A). Here, surfaces of the regions **2612** and **2613** of the substrate **2600** which does not overlap with the conductive films **2640** and **2642** respectively are exposed.

Specifically, in the region **2612** of the substrate **2600**, a part of the insulating film **2632** formed below the conductive film **2640**, which does not overlap with the conductive film **2640**, is selectively removed, so that the ends of the conductive film **2640** and the ends of the insulating film **2632** are almost aligned with each other. In addition, in the region **2613** of the substrate **2600**, a part of the insulating film **2634** formed below the conductive film **2642**, which do not overlap with the conductive film **2642**, is selectively removed, so that the ends of the conductive film **2642** and the ends of the insulating film **2634** are almost aligned with each other.

In this case, the part of the insulating films or the like which do not overlap with the conductive films **2640** and **2642** may be removed at the same time as the formation of the conductive films **2640** and **2642**. Alternatively, the part of the insulating films which do not overlap with the conductive films **2640** and **2642** may be removed using resist masks which are left after the formation of the conductive films **2640** and **2642** or the conductive films **2640** and **2642** as masks.

Then, the regions **2612** and **2613** of the substrate **2600** are selectively doped with an impurity element (see FIG. **27**B). At this time, the region **2613** is selectively doped with an n-type impurity element at low concentration, using the conductive film **2642** as a mask, whereas the region **2612** is selectively doped with a p-type impurity element at low concentration, using the conductive film **2640** as a mask. As an n-type impurity element, phosphorus (P), arsenic (As), or the like can be used. As a p-type impurity element, boron (B), aluminum (Al), gallium (Ga), or the like can be used.

Next, sidewalls **2654** which are in contact with the side surfaces of the conductive films **2640** and **2642** are formed. Specifically, the sidewalls are formed with a single layer or a stacked layer of a film containing an inorganic material such as silicon, silicon oxide, or silicon nitride, or a film containing an organic material such as an organic resin. Then, such an insulating film is selectively etched by anisotropic etching mainly in the perpendicular direction, so that the sidewalls **2654** can be formed so as to be in contact with the side surfaces of the conductive films **2640** and **2642**. The sidewalls **2654** are used as masks in doping for forming LDD (Lightly Doped Drain) regions. In addition, the sidewalls **2654** are formed to be in contact with side surfaces of the insulating films formed below the conductive films **2640** and **2642**.

Next, the regions **2612** and **2613** of the substrate **2600** are doped with an impurity element, using the sidewalls **2654** and the conductive films **2640** and **2642** as masks, so that impurity regions which function as source and drain regions are formed (see FIG. **27**C). At this time, the region **2613** of the substrate **2600** is doped with an n-type impurity element at high concentration, using the sidewalls **2654** and the conductive film **2642** as masks, whereas the region **2612** is doped with a p-type impurity element at high concentration, using the sidewalls **2654** and the conductive film **2640** as masks.

As a result, impurity regions **2658** which form source and drain regions, low concentration impurity regions **2660** which form LDD regions, and a channel formation region **2656** are formed in the region **2612** of the substrate **2600**. Meanwhile, impurity regions **2664** which form source and drain regions, low concentration impurity regions **2666** which form LDD regions, and a channel formation region **2662** are formed in the region **2613** of the substrate **2600**.

In this embodiment, the impurity elements are introduced under the condition that parts of the regions **2612** and **2613** of the substrate **2600** which do not overlap with the conductive films **2640** and **2642** are exposed. Accordingly, the channel formation regions **2656** and **2662** which are formed in the regions **2612** and **2613** of the substrate **2600** respectively can be formed in a self-aligned manner, due to the conductive films **2640** and **2642**.

Next, a second insulating film **2677** is formed so as to cover the insulating films, the conductive films, and the like which are provided over the regions **2612** and **2613** of the substrate **2600**, and opening portions **2678** are formed in the second insulating film **2677** (see FIG. **28**A).

The second insulating film **2677** can be formed with a single layer or a stacked layer of an insulating film containing oxygen and/or nitrogen such as silicon oxide (SiO_x), silicon nitride (SiN_x), silicon oxynitride (SiO_xN_y, where x>y>0), or silicon nitride oxide (SiN_xO_y, where x>y>0); a film containing carbon such as DLC (Diamond-Like Carbon); an organic material such as epoxy, polyimide, polyamide, polyvinyl phenol, benzocyclobutene, or acrylic; or a siloxane material such as a siloxane resin, by a CVD method, a sputtering method or the like. A siloxane material corresponds to a material having a bond of Si—O—Si. Siloxane has a skeleton structure with the bond of silicon (Si) and oxygen (O). As a substituent of siloxane, an organic group containing at least hydrogen (e.g., an alkyl group or aromatic hydrocarbon) is used. In addition, a fluoro group may be used as the substituent. Further, a fluoro group and an organic group containing at least hydrogen may be used as the substituent.

Next, conductive films **2680** are formed in the opening portions **2678** by a CVD method. Then, conductive films **2682***a* to **2682***d* are selectively formed over the insulating film **2677** so as to be electrically connected to the conductive films **2680** (see FIG. **28**B).

The conductive films **2680** and **2682***a* to **2682***d* are formed with a single layer or a stacked layer of an element selected from aluminum (Al), tungsten (W), titanium (Ti), tantalum (Ta), molybdenum (Mo), nickel (Ni), platinum (Pt), copper (Cu), gold (Au), silver (Ag), manganese (Mn), neodymium (Nd), carbon (C), or silicon (Si), or an alloy material or a compound material containing such an element as its main component by a CVD method, a sputtering method or the like. An alloy material containing aluminum as its main component corresponds to, for example, a material which contains aluminum as its main component and also contains nickel, or a material which contains aluminum as its main component and also contains nickel and one or both of carbon and silicon. For example, each of the conductive films **2680** and **2682***a* to **2682***d* is preferably formed to have a stacked structure of a barrier film, an aluminum-silicon (Al—Si) film, and a barrier film or a stacked structure of a barrier film, an aluminum silicon (Al—Si) film, a titanium nitride film, and a barrier film. It is to be noted that the "barrier film" corresponds to a thin film formed of titanium, titanium nitride, molybdenum, or molybdenum nitride. Aluminum and aluminum silicon are suitable materials for forming the conductive films **2680** and **2682***a* to **2682***d* because they have high resistance values and are inexpensive. When barrier layers are provided as the top layer and the bottom layer, generation of hillocks of aluminum or aluminum silicon can be prevented. When a barrier film formed of titanium which is an element having a high reducing property is formed, even when there is a thin natural oxide film formed on the crystalline semiconductor film, the natural oxide film can be chemically reduced, and a favorable contact between the conductive film **2680** and **2682***a* to **2682***d*, and the crystalline semiconductor film can be obtained. Here, the conductive films **2680** and **2682***a* to **2682***d* can be formed by selective growth of tungsten (W) by a CVD method.

Through the above steps, a p-channel transistor formed in the region **2612** of the substrate **2600** and an n-channel transistor formed in the region **2613** of the substrate **2600** can be obtained.

It is to be noted that the structure of transistors constituting the radio field intensity measurement device of the present invention is not limited to the one shown in the drawings. For example, a transistor with an inversely staggered structure, a FinFET structure, or the like can be used. A FinFET structure is preferable because it can suppress a short channel effect which occurs along with reduction in transistor size.

The radio field intensity measurement device of the present invention is provided with a battery by which power can be stored in the signal processing circuit. As the battery, a capacitor such as an electric double layer capacitor or a thin-film secondary battery is preferably used. In this embodiment, a connection between the transistor formed in this embodiment and a thin-film secondary battery will be described.

In this embodiment, a secondary battery is stacked over the conductive film **2682***d* connected to the transistor. The secondary battery has a structure in which a current-collecting thin film, a negative electrode active material layer, a solid electrolyte layer, a positive electrode active material layer, and a current-collecting thin film are sequentially stacked (see FIG. **28**B). Therefore, the material of the conductive film **2682***d* which is also used as the material of the current-collecting thin film of the secondary battery preferably has high adhesion to the negative electrode active material layer and also low resistance. In particular, aluminum, copper, nickel, vanadium, or the like is preferably used.

Subsequently, the structure of the thin-film secondary battery is described. A negative electrode active material layer **2691** is formed over the conductive film **2682***d*. In general, vanadium oxide (V_2O_5) or the like is used. Next, a solid electrolyte layer **2692** is formed over the negative electrode active material layer **2691**. In general, lithium phosphate (Li_3PO_4) or the like is used. Next, a positive electrode active material layer **2693** is formed over the solid electrolyte layer **2692**. In general, lithium manganate ($LiMn_2O_4$) or the like is used. Lithium cobaltate ($LiCoO_2$) or lithium nickel oxide ($LiNiO_2$) can also be used. Next, a current-collecting thin film **2694** to serve as an electrode is formed over the positive electrode active material layer **2693**. The current-collecting thin film **2694** should have high adhesion to the positive electrode active material layer **2693** and also low resistance. For example, aluminum, copper, nickel, vanadium, or the like can be used.

Each of the above-described thin layers of the negative electrode active material layer **2691**, the solid electrolyte layer **2692**, the positive electrode active material layer **2693**, and the current-collecting thin film **2694** may be formed by a sputtering technique or an evaporation technique. In addition, the thickness of each layer is preferably 0.1 to 3 μm.

Next, an interlayer film **2696** is formed by application of a resin. The interlayer film **2696** is etched to form a contact hole. The interlayer film **2696** is not limited to a resin, and other films such as a CVD oxide film may also be used; however, a resin is preferably used in terms of flatness. In addition, the contact hole may be formed without etching, but using a photosensitive resin. Next, a wiring layer **2695** is formed over the interlayer film **2696** and is connected to a wiring **2697**. Thus, an electrical connection between the thin-film secondary battery and the transistor is obtained by the connection with the wiring **2697**.

With the above-described structure, the radio field intensity measurement device of the present invention can have a structure in which transistors are formed on a single crystal substrate and a thin-film secondary battery is formed thereover. Thus, the radio field intensity measurement device of the present invention can achieve flexibility as well as thinning and reduction in size.

The method of manufacturing the radio field intensity measurement device in this embodiment can be applied to any of the radio field intensity measurement devices in the other embodiments.

Embodiment 4

Embodiment 4 will describe applications of the radio field intensity measurement device of the present invention. The radio field intensity measurement device of the present invention can protect an object which may malfunction due to a radiowave of medical equipment, pace makers or the like, and can visibly informs us that the intensity of the radiowave around the object is high. Thus the radio field intensity measurement device of the present invention can be used as a so-called radio field intensity detector.

In this embodiment, with reference to FIGS. **29**A to **36**B, application examples of the present invention and examples of products in the application examples are described.

FIG. **29**A illustrates an example of a completed radio field intensity detector according the present invention. A radio field intensity measurement device **3001** is formed on a checking badge **3000**. On the checking badge **3000**, an ID **3002** and a photograph **3003** of an operator wearing the checking badge is attached. The checking badge **3000** like this, as illustrated in FIG. **29**B, is attached on work clothes **3004** of the operator. The operator has the radio field intensity detector and confirms color changed of the radio field intensity measurement device **3001**, when the operator enters an area with extremely intense radiowave. At this time, the operator can know the intensity of radiowave. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **29**A, the operator can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

FIG. **30**A illustrates an example of a completed radio field intensity detector according to the present invention. On a seal **3100**, a warning mark **3101** to warn someone not to use a device sending a radiowave and a radio field intensity measurement device **3102** are formed. The seal **3100** like this is attached to a medical device **3103** in a hospital as illustrated in FIG. **30**B for example. When a visitor or a hospital patient comes near the radio field intensity measurement device **3102**, having a device sending a radiowave whose power is not switched off, the color of the radio field intensity measurement device **3102** is changed to send a visible warning and tell the visitor or the hospital patient to switch off the device sending radiowave. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **30**A, a visitor or a hospital patient can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

FIG. **31**A illustrates an example of a completed radio field intensity detector according to the present invention. On a seal **3200**, a warning mark **3201** to warn someone not to use a cellular phone and a radio field intensity measurement device **3202** are formed. The seal **3200** like this is attached to a strap **3203** near priority seating in a train as illustrated in FIG. **31**B for example. When a passenger has a cellular phone whose power is not switched off and an antenna **3205** of the cellular phone **3204** sends radiowave, the color of the radio field intensity measurement device **3202** is changed due to a radiowave to visibly warn the passenger to switch off the cellular phone. In addition, someone has or wear an object which may malfunction due to radiowave, such as a pace maker, he/she can sense a risk of the malfunction by seeing the color of the radio field intensity measurement device, and he/she can leave the source of radiowave. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **31**A, a passenger can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

FIG. **32**A illustrates an example of a completed radio field intensity detector according to the present invention. On a warning light **3300**, a warning mark **3301** incorporating the radio field intensity measurement device of the present invention is formed. The warning light like this is used in an airplane **3302** as illustrated in FIG. **32**B for example. Specifically, as illustrated in FIG. **32**C, the warning light **3300** is installed above seats **3303**. When an airplane takes off, a flight attendant confirms the warning light. If a source emitting a radiowave is around, the flight attendant warns passengers to switch off the source. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **32**A, a flight attendant can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight, so that the radio field intensity detector works as a security device in the public vehicle.

FIG. **33**A illustrates an example of a completed radio field intensity detector according to the present invention. On a warning light **3400**, a warning mark **3401** incorporating the radio field intensity measurement device of the present invention is formed. The warning light like this is incorporated in an electromagnetic cooker (or an induction heating (IH) cooker) **3402** as illustrated in FIG. **33**B for example. When the electromagnetic cooker is broken and emits dangerous electromagnetic wave around, the color of the warning light is changed to notify danger. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **33**A, a user can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

FIG. **34**A illustrates an example of a completed radio field intensity detector according to the present invention. On a display portion **3405**, a warning mark **3406** incorporating the radio field intensity measurement device of the present invention is formed. The display portion like this is incorporated in a microwave oven **3407** as illustrated in FIG. **34**B for example. When the microwave oven **3407** is broken and emits dangerous electromagnetic wave around, the color of the warning light is changed to notify danger. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **34**A, a user can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

FIG. **35**A is an example of a completed radio field intensity detector according to the present invention. On a seal **3500**, a radio field intensity measurement device **3501** is formed. The seal **3500** like this is attached on a computer **3502** as illustrated in FIG. **35**B for example. A user of the computer can know the intensity of a radiowave used in radio communication by the color change of the radio field intensity measurement device **3501**. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **35**A, a user can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

FIG. **36**A illustrates an example of a completed radio field intensity detector according to the present invention. On a plate **3600**, a radio field intensity measurement device **3601** is formed. The plate **3600** like this is attached on an inner wall of a radiowave measurement room **3602** as illustrated in FIG. **36**B. A design engineer of an antenna sends a radiowave by using the computer **3603** through an antenna **3604**, and confirms the color change of the inner wall of the radiowave measurement room. Thus, the distribution of the radiowave is observed in a visible manner and the performance of the antenna **3604** can be measured. The radio field intensity measurement device of the present invention can measure a weak radiowave from a long distance, and has excellent visibility even when brightness in surroundings is intense e.g., under sunlight. Therefore, in the radio field intensity detector of FIG. **36**A, a user can measure a weak radiowave from a long distance and can see the measured result with excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

As described above, the radio field intensity measurement device of the present invention can be provided in any object (including creatures) of which the level of radiowave is to be detected.

This embodiment can be freely combined with any of the other embodiment modes and embodiments. In other words, a radio field intensity detector including the radio field intensity measurement device of the preset invention can measure a weak radiowave from a long distance, and can have excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

Embodiment 5

Embodiment 5 will describe application of a radio field intensity detector of the present invention. The radio field intensity detector using the radio field intensity measurement device of the present invention can be used as an amusement device utilizing a radiowave as colors.

In this embodiment, application examples of the present invention and examples of products in the application examples are described with reference to FIGS. **37**A and **37**B.

FIG. **37**A illustrates an example of a completed radio field intensity detector according to the present invention. On a plate **3700**, a radio field intensity measurement device **3701** is formed. A thin plastic plate is used as the plate **3700**, and transistors forming the radio field intensity measurement device is formed on the thin plastic substrate, so that it can be processed to be curved.

In the game console of this embodiment, a plurality of the plates **3700** in FIG. **37**A are combined to form a plate-like radio field intensity detector **3710** having a height as high as a man, as illustrated in FIG. **37**B. A user **3702** sends a radiowave by swinging around a stick **3704** including a radiowave emitter **3703**, and enjoys color change of the plate-like radio field intensity detector **3710**.

Sending of a radiowave by the user is interlocked with the movement of the user **3702** by combining a sensor such as an acceleration sensor or a piezoelectric sensor including a microphone or the like incorporated in the stick **3704** to entertain the amusement device more. In addition, in FIG. **37**B, the stick **3704** is illustrated as a member including a radiowave emitter; however, is not limited to a stick shape, and the member including a radiowave emitter may be operative by interlocking with the movement of human body.

This embodiment employs a flat plate-like shape for the plate-like radio field intensity detector **3710**; however, may another shape such as sphere or irregular surface to enjoy the color change. Further, by combining a liquid crystal display device or a light-emitting device, an amusement device having wide visible variation may be formed.

As described above, a radio field intensity measurement device of the present invention can be provided in any object (including creatures) of which the level of the radiowave is to be detected.

This embodiment can be freely combined with any of the other embodiment modes and embodiments. In other words, a radio field intensity detector including the radio field intensity measurement device of the preset invention can measure a weak radiowave from a long distance, and can have excellent visibility even when brightness in surroundings is intense e.g., under sunlight.

This application is based on Japanese Patent Application serial No. 2006-309996 filed in Japan Patent Office on Nov. 16, 2006, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A device comprising:

a circuit comprising a transistor attached to a sheet material;

a conductive film electrically connected to the transistor;

a thin film battery electrically connected to the conductive film through an anisotropic conductive film or an anisotropic conductive paste; and

a display element electrically connected to the circuit, wherein the transistor comprises indium, zinc and oxygen.

2. The device according to claim **1**, wherein the sheet material is a film in which an antistatic material is dispersed in a resin, or a film to which an antistatic material is attached.

3. The device according to claim **1**, wherein the device is a radio field intensity measurement device.

4. The device according to claim **1**, wherein the conductive film is an antenna.

5. The device according to claim **1**,

wherein the conductive film is configured to convert a received radiowave to an induction signal, and

wherein the thin film battery is charged by a direct signal generated from the induction signal.

6. The device according to claim **4**, wherein the antenna is one selected from the group consisting of a dipole antenna, a loop antenna, a Yagi antenna, a patch antenna, and a minute antenna.

7. The device according to claim **1**, wherein the display element comprises a resistance heating element and a thermochromic element.

8. The device according to claim **1**, wherein the display element comprises a voltage application element and an electrochromic element.

9. A device comprising:

a circuit comprising a transistor attached to a sheet material;

a conductive film electrically connected to the transistor;

a thin film battery electrically connected to the conductive film through an anisotropic conductive film or an anisotropic conductive paste; and

a display element electrically connected to the circuit,

wherein the transistor comprises indium, zinc and oxygen, and

wherein a color of the display element is changed in accordance with a radiowave received by the conductive film.

10. The device according to claim **9**, wherein the radiowave is sent from a computer or a stick including a radiowave emitter.

11. The device according to claim **9**, wherein the sheet material is a film in which an antistatic material is dispersed in a resin, or a film to which an antistatic material is attached.

12. The device according to claim **9**, wherein the device is a radio field intensity measurement device.

13. The device according to claim **9**, wherein the conductive film is an antenna.

14. The device according to claim **9**,

wherein the conductive film is configured to convert a received radiowave to an induction signal, and

wherein the thin film battery is charged by a direct signal generated from the induction signal.

15. The device according to claim **13**, wherein the antenna is one selected from the group consisting of a dipole antenna, a loop antenna, a Yagi antenna, a patch antenna, and a minute antenna.

16. The device according to claim **9**, wherein the display element comprises a resistance heating element and a thermochromic element.

17. The device according to claim **9**, wherein the display element comprises a voltage application element and an electrochromic element.

* * * * *